GREEN INFRASTRUCTURE BASELINE INVENTORY

APRIL 2015

Sponsored by the *Fund For Lake Michigan*

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ABBREVIATIONS

BMP	Best Management Practice
GIBI	*Green Infrastructure Baseline Inventory Report, August 2014*
GIS	Geographic Information System
MMSD	Milwaukee Metropolitan Sewerage District
RGIP	*Regional Green Infrastructure Plan* (MMSD)
OES	City of Milwaukee Office of Environmental Sustainability
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids

DEFINITIONS

BaseTern	An underground stormwater management or rainwater harvesting structure created from the former basement of an abandoned home that has been slated for demolition.
Bioretention	(Also Rain Garden) Shallow vegetated basin that collects and absorbs runoff from rooftops, sidewalks, and streets; also mimics natural hydrology by infiltrating and evapotranspiring runoff.
Bioswale	Vegetated, mulched, or xeriscaped channel that provides treatment and retention as it moves stormwater from one place to another.
Green Infrastructure	Practice which uses natural hydrologic features to manage water and provide environmental and community benefits.
Green Roof	Roof covered with growing media and vegetation that enable rainfall infiltration and evapotranspiration of stored water.
Green Street	(Also Green Alley) Integrates green infrastructure elements into the design to store, infiltrate, and evapotranspire stormwater; includes elements such as permeable pavement, bioswales, and stormwater trees.
Permeable Pavement	Paved surfaces that infiltrate, treat, and/or store stormwater where it falls; may be constructed from pervious concrete, porous asphalt, permeable interlocking pavers, or other materials.
Rainwater Catchment	(Cistern or Rain Barrel) System that channels rainwater from impervious surfaces into storage tank for later use.
Stormwater Tree	Street tree installed in site engineered for stormwater management by optimizing site design, soil composition, and soil compaction to increase stormwater uptake and maximum tree growth.

EXECUTIVE SUMMARY

The City of Milwaukee developed the *Green Infrastructure Baseline Inventory (GIBI)* to satisfy a major target of the Water Chapter of the *ReFresh Milwaukee* Sustainability Plan, which is to establish baseline measures of impervious surfaces and existing green infrastructure within the city limits.

ReFresh Milwaukee proposes an annual 10% volume increase captured by green infrastructure. Therefore, the *GIBI* will be utilized to design and plan strategy implementation that can achieve a target of increasing stormwater runoff capture through green infrastructure. Additionally, the Milwaukee Metropolitan Sewerage District (MMSD) published the *2035 Vision* and *Regional Green Infrastructure Plan* which stipulate the capture of the first half-inch of rainfall on impervious surface in its service area, which equals 740 million gallons.

The city of Milwaukee's land area is comprised of 96.1 square miles. Of this, 45.5%, or 43.7 square miles, is covered by impervious surface. One inch of rainfall on the impervious area of the city would produce 760 million gallons of stormwater runoff. Capturing the first half-inch of rainfall from all impervious surface area would require the collection of approximately 380 million gallons of stormwater runoff. Alternatively, the city comprises 23.4% of MMSD's service area; prorating the city's land area as a percentage of MMSD's service area yields a smaller target of capturing 173 million gallons of stormwater runoff[1].

KEY METRICS:

- City of Milwaukee land area: 96.1 square miles (61,504 acres)
- Percent impervious surface: 45.5%
- Existing shoreline length: 163.4 miles (862,633 linear feet)
- Volume capture of existing green infrastructure: 14 million gallons
- ReFresh Milwaukee green infrastructure capture goal: 36 million gallons by 2023
- MMSD green infrastructure capture goal: 173 – 380 million gallons by 2035

The inventory of known, existing green infrastructure present in the city reveals approximately 14 million gallons of stormwater capture volume. City of Milwaukee planned green infrastructure projects would increase the potential storage capacity by 19.5 million gallons to equal a total of 33.5 million gallons.

ReFresh Milwaukee proposes that the volume of water captured through green infrastructure increases by 10% annually, equal to 36 million gallons through 2023. Conversely, adopting the goals stipulated by MMSD for stormwater runoff reduction of 173 million gallons would require enough green infrastructure to capture approximately 10 million additional gallons annually, an ambitious and expensive figure.

The *GIBI* does not establish green infrastructure targets but rather provides a baseline inventory of current, known, citywide green infrastructure installations, as well as impervious surfaces. The Green Infrastructure Plan, to be completed in the near future, will include recommendations and targets for capturing stormwater. The City of Milwaukee is committed to stormwater mitigation. However, full implementation of the MMSD goals as estimated for the City[2], would require long-term political commitment, immediate action, and substantial capital investment.

[1] Multiplying 740 million gallons by 0.234 equals 173.2 million gallons: the City's portion based on percentage of land in MMSD's service area.

[2] MMSD set regional goals for stormwater capture and green infrastructure implementation, but did not specify how municipalities in its service area would meet them.

INTRODUCTION

The City of Milwaukee developed this *Green Infrastructure Baseline Inventory* (*GIBI*) for planning purposes related to stormwater management and to satisfy the first goal of the Water chapter of the *ReFresh Milwaukee* sustainability plan. Funding for the project was provided by the Fund for Lake Michigan through Grant #20121443. Approval by the City of Milwaukee Common Council was granted in Council File #131035.

The objectives for the *GIBI* are:

- Determine the total impervious surface area in the city, including public infrastructure, private property, and public property.
- Establish linear feet of shoreline (lakes, riparian corridors, and surface drainage ways) and identify the amount possessing properly maintained vegetative buffer zones.
- Catalog and quantify the existing green infrastructure sites and current capture volumes.
- Identify areas prone to surface flooding and basement water infiltration and/or backups due to topography.
- Calculate the City's targets with respect to annual stormwater runoff reductions through green infrastructure best management practices (BMP) implementation, as established in the Milwaukee Metropolitan Sewerage District's *2035 Vision* and *Regional Green Infrastructure Plan*.

The results of the *GIBI* can be used to determine the highest priority locations to implement green infrastructure BMPs in the city, which may decrease the risks of localized flooding and the volume of clear water entering the sewer pipes leading to basement backups, and increase the quality of stormwater runoff entering area waterways. The information found in the *GIBI* also gives City planners a starting point for designing and developing adequate green infrastructure projects to meet the annual stormwater runoff flow reductions and rainfall capture volume targets proposed in *ReFresh Milwaukee*.

BACKGROUND

The *ReFresh Milwaukee* Sustainability Plan

ReFresh Milwaukee was released by Mayor Tom Barrett and adopted by the Common Council in 2013. As Milwaukee's first sustainability plan, it functions as a strategic vision and framework for the city to become a more sustainable community. While it addresses many important factors affecting sustainability in the city, water is a key component of the plan.

The Water Chapter of *ReFresh Milwaukee* provides a roadmap for community water sustainability over the next ten years, and aims to make Milwaukee the Water-Centric City of the United States. It sets goals and targets for individuals and organizations to achieve and provides a citywide roadmap for improving the environmental, economic, and social conditions of Milwaukee's neighborhoods. The Plan is a call to action for the community, and connects residents, businesses, and other groups working on sustainability issues.

One of the four goals for the Water Chapter of *ReFresh Milwaukee* is to reduce stormwater runoff and clear water entering the sewer system. The targets listed below have been identified to achieve this; the *GIBI* addresses the first objective:

- Establish baseline measures of impervious surface and green infrastructure on a citywide basis.
- Create a City green infrastructure policy plan.
- Develop a regional climate change resiliency plan that uses the best available atmospheric science, via city collaboration with partners.
- Increase the volume of stormwater runoff captured through green infrastructure by 10% annually.

Stormwater in urban environments can be managed with grey infrastructure and/or green infrastructure. Grey infrastructure is comprised of impervious surfaces used to convey, treat, or store water and is the traditional means for stormwater management in developed communities. Storm sewers, gutters, and pipes are some examples. Grey infrastructure is utilized as storage or to move stormwater from one location to another; it is not designed to mitigate flow.

Green infrastructure aims to reduce the quantity of stormwater runoff produced by utilizing the natural processes of evaporation, evapotranspiration, and infiltration. Not only do these practices retain more stormwater on site, but they also slow the velocity of flow that is produced. Additionally, some green infrastructure strategies are capable of reducing pollutant loads in runoff. Examples of green infrastructure include bioswales, green roofs, rain gardens, rain barrels, and permeable pavement.

The highest priority strategies of the Water Chapter in *ReFresh Milwaukee* are to develop a Green Infrastructure Policy Plan and implementation procedures for the City. These are to be based in sound science and recent data, and aligned with regional stormwater and water quality goals promulgated in the *Regional Green Infrastructure Plan* (Milwaukee Metropolitan Sewerage District) and the *Water Quality Initiative* (Milwaukee Metropolitan Sewerage District and Southeastern Wisconsin Regional Planning Commission).

When completed, the Green Infrastructure Plan will:

- Develop recommendations for city-controlled and privately-owned assets.
- Review City policies and ordinances, and amend them as needed to support and encourage green infrastructure.
- Identify high-priority locations for implementing green infrastructure.
- Replicate the Green Corridor model, which serves as a showcase for green technologies and is located on South 6th Street from Howard Avenue to College Avenue in the 13th Aldermanic District (the Garden District), to other areas of the city and maximize installation of community gardens, native landscaping, bioswales, green roofs, permeable pavement, and water recycling projects.
- Link to city sustainable building design guidelines.
- Identify incentives and innovative financing approaches for full-scale implementation.

The information and data contained in the *GIBI* can be used as a starting point in developing the City's Green Infrastructure Plan.

Milwaukee Metropolitan Sewerage District's *2035 Vision*

In 2010, the Milwaukee Metropolitan Sewerage District (MMSD) published the *2035 Vision*, a framework for MMSD as it aims to achieve a healthier region and cleaner Lake Michigan. This mission will be accomplished through the objectives of attaining zero overflows, zero basement backups, and improving stormwater management. MMSD intends to become a model in its management of impacts from wet weather due to climate change, and focus on energy efficiency and sustainable operations.

The main objective of the *2035 Vision* is Integrated Watershed Management. Integrated Watershed Management's primary focus is to seek a balance between grey and green infrastructure in Milwaukee's watersheds while incorporating inter-jurisdictional opportunities and limitations. MMSD's goals for Integrated Watershed Management include:

- Support a watershed-based permitting program and water quality trading program to cost-effectively improve environmental performance.
- Collaborate with area partners with intent of reducing basement backup occurrences to zero.
- Collaborate with area partners to reduce Combined Sewer Overflow and Separated Sewer Overflow occurrences to zero, as feasibility allows.
- Work in partnership to remove homes from the 1% probability floodplains.
- Protect an additional 10,000 acres of natural river buffer through GreenSeams® and other regional programs.
- Capture the first half inch of rainfall on impervious surfaces with green infrastructure strategies.
- Harvest the first quarter inch per square foot of rainfall.

Capturing the first half-inch of rainfall from impervious surfaces, including an adjustment for tree cover, within the MMSD service area equals 740 million gallons of stormwater storage. This information is provided in the *Regional Green Infrastructure Plan* on page five.

Milwaukee Metropolitan Sewerage District's *Regional Green Infrastructure Plan*

MMSD created the *Regional Green Infrastructure Plan (RGIP)* in 2013 as a guideline on how to meet the *2035 Vision* of capturing the first half inch of rainfall on impervious surfaces with green infrastructure, the equivalent of 740 million gallons. Through extensive mapping and analysis, the quantity of impervious surfaces (streets, buildings, and parking lots) was calculated for each watershed within the MMSD service area, which consists of 28 municipalities over 411 square miles and includes, all or portions of six watersheds in Southeastern Wisconsin. This information was then utilized to determine the quantities and costs of different green infrastructure strategies that could feasibly be implemented to meet the 2035 stormwater runoff capture goal for MMSD's service area.

The Milwaukee *Green Streets Stormwater Management Plan*

Milwaukee is planning streets designed to reduce stormwater flooding risks, improve the quality of lakes and rivers by increasing the quality of runoff entering local waterways, and help the city adapt to climate change through the installation of green infrastructure strategies.

The *Green Streets Stormwater Management Plan* was adopted in 2013 to assist the city with achieving Wisconsin Department of Natural Resources requirements to reduce Total Suspended Solids (TSS) and meet future Total Maximum Daily Loads (TMDLs). To accomplish this, Green Streets' goals include decreasing the quantity of polluted stormwater entering the city's waterways and diminishing peak flows and volumes during storm events to reduce surface flooding, basement backups, and Combined Sewer Overflows.

The Green Streets program utilizes green infrastructure strategies, such as bioretention and permeable paving, to reduce stormwater runoff and increase on-site infiltration. Native landscaping and stormwater trees are also incorporated into designs to filter pollution, aid in infiltration, and increase runoff capture.

Implementation of Green Streets strategies is not feasible for all repaving, reconstruction, or new right-of-way construction due to economic and physical constraints. Factors that may impede installation of green infrastructure include high density development, slopes greater than 12% grade, minimal property set-backs of less than 15 feet, bedrock depth of less than six feet, and groundwater depth fewer than six feet below grade.

Guidelines for implementing Green Streets have been developed to determine which strategies are most suitable for each project; these are summarized below. Table 1, on page 9, is a matrix developed to aid planners and designers in deciding which green infrastructure strategies are most appropriate for each situation.

Types of Green Infrastructure Strategies for Retrofitting Existing Rights-of-Way:

- Using less impervious surface in reconstructed street or alley by narrowing the street width to reduce impervious surface
- Using existing or newly-created green space for green street stormwater strategies
- Installing depressed median for bioretention versus raised median
- Implementing porous pavement within the pavement cross-section in low traffic areas

Table 1: GREEN STREETS STRATEGY APPLICABILITY MATRIX			
	GI STRATEGY TYPE:		
STREET CLASSIFICATION:	BIORETENTION	POROUS PAVEMENT	TREE TRENCH
LOCAL (Residential streets, low traffic volume, typically no median)	*YES* Applicable on wide terraces & medians (although few medians exist on surface streets).	*YES* Applicable on entire low traffic volume streets or in parking lanes.	*YES* Applicable on terraces & medians (although few medians exist on surface streets).
COLLECTOR (Feeder street for arterial street, medium traffic volume, few medians)	*YES* Applicable on wide terraces & medians.	*YES* Applicable in parking lanes.	*YES* Applicable on terraces & medians.
MINOR ARTERIAL (similar to Major Arterial)	*YES* Applicable on wide terraces & medians.	*YES* Applicable in parking lanes.	*YES* Applicable on terraces & medians.
MAJOR ARTERIAL (high traffic volume, likely median, likely parking restrictions during peak hours)	*YES* Applicable on wide terraces & medians.	*MAYBE* Applicable in parking lanes where parking lanes are not used for peak travel lanes.	*YES* Applicable on terraces & medians.
ALLEY	*NOT LIKELY*	*YES* Depending on traffic characteristics (trash & delivery trucks, etc.).	*NOT LIKELY*
SERVICE DRIVE (parallel road to major road which provides local access, low traffic volume)	*YES* Applicable on wide terraces.	*YES* Applicable on entire low traffic volume streets or in parking lanes.	*YES* Applicable on terraces.

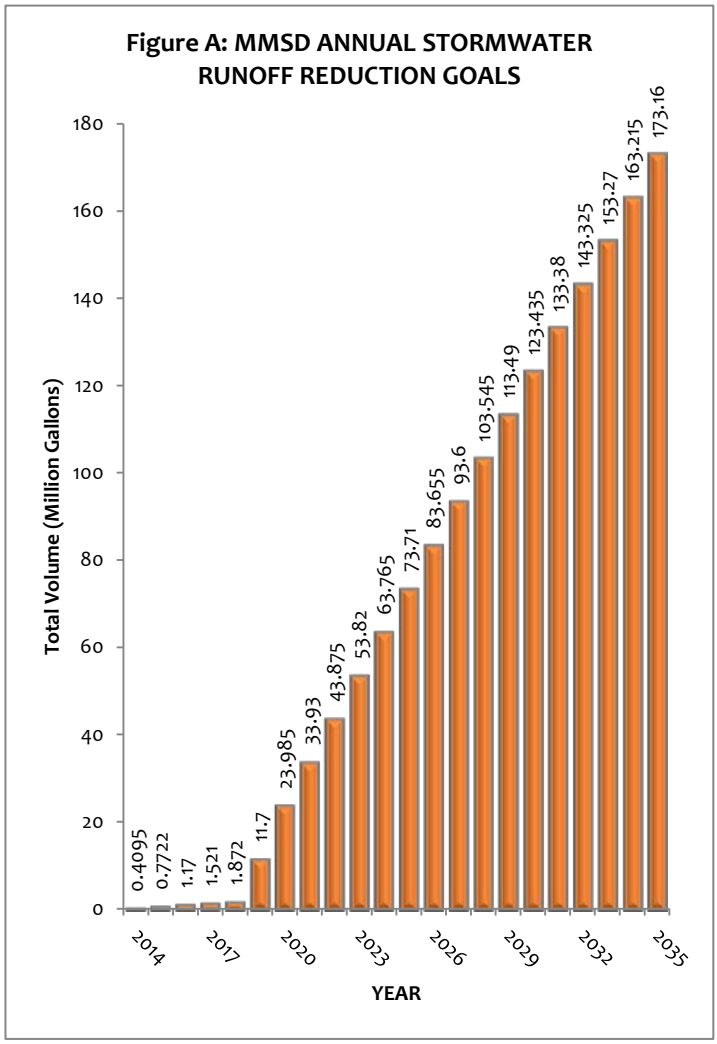
The *2014 Sustainable Municipal Water Management Public Evaluation Report*

The *2014 Sustainable Municipal Water Management Public Evaluation Report* was published in 2014 by the City of Milwaukee, in conjunction with MMSD and the Milwaukee Water Works, as part of the Great Lakes and St. Lawrence Cities Initiative's Stormwater Management initiative. The inaugural *Report* outlines and highlights the City's progress in six principle areas:

- Water Conservation and Efficiency
- Shared Water Stewardship
- Shoreline and Waterways Restoration
- Water Pollution Prevention
- Water Protection Planning
- Water Preparedness for Climate Change

Many of the milestones addressed in the *Report* align with objectives presented in *ReFresh Milwaukee*'s Water Chapter, and identify key areas where the City is working to reduce stormwater runoff. Increasing the quantity of green infrastructure, restoring riparian corridors to natural states by removing concrete channels, and developing a climate change resiliency plan are all steps the City is taking to reduce surface flooding, clear water infiltration of the sewer systems, and basement backups through decreasing the amount of stormwater flow during and after rain events.

GREEN INFRASTRUCTURE CAPTURE TARGETS



MMSD's *RGIP* details stormwater runoff and green infrastructure achievement targets for the MMSD service area for 2035. The primary objective of the *2035 Vision* is to capture the first half inch of rainfall per storm event from impervious surfaces, which is equivalent to 740 million gallons of storage, over 411 square miles comprising the MMSD service area.

The City of Milwaukee makes up 23.4% of MMSD's service area; based on prorated land area, the city's proportional equivalent stormwater capture of the first half inch of rainfall is calculated to be 173.2 million gallons (23.4% of 740 million gallons). If Milwaukee adopts the MMSD target, the timetable and corresponding capture goals are outlined in Figure A.

These runoff reduction goals would start out slowly to allow the City additional time to design and plan for implementation. In 2019 and 2020, stormwater targets experience a significant increase. Beginning in 2021, the additional increment for runoff reduction through 2035 is equal to almost 10 million gallons annually.

The City's objective of reducing stormwater runoff and increasing capture through green infrastructure by 10% annually is one of the main goals outlined in *ReFresh Milwaukee*'s Water Chapter. The stormwater capture volume under the *ReFresh Milwaukee* plan is lower than those presented by MMSD, however. The total capture volume would be equal to 36 million gallons by 2023, which is the time frame specified in *ReFresh Milwaukee* for meeting goals and objectives.

At this point in time, decisions and policies regarding the actual volume of stormwater runoff capture, types and quantities of green infrastructure to be constructed, and timetable for implementation, have not yet been finalized by the City of Milwaukee. These will be addressed in the forthcoming Green Infrastructure Plan.

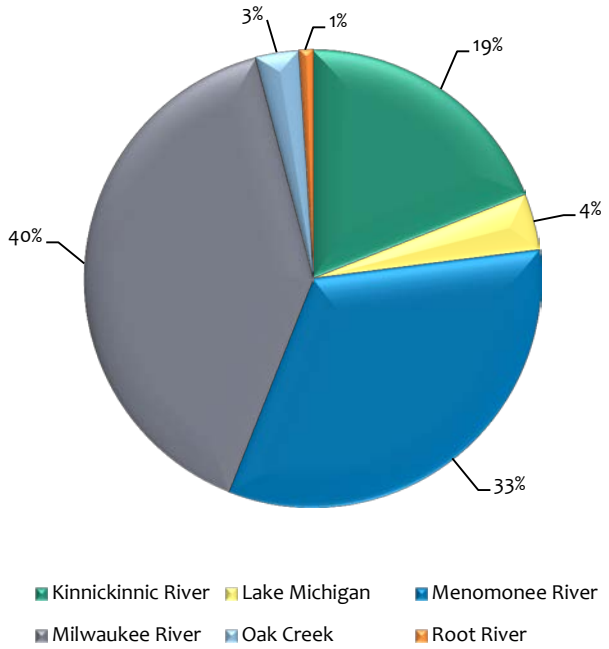
MILWAUKEE'S GEOGRAPHY

The City of Milwaukee comprises a land area of 96.1 square miles and is situated at the confluence of the Milwaukee, Menomonee, and Kinnickinnic Rivers. The city's terrain was created by glacial movement. Elevation is generally higher in the western region and declines closer to the lake, with the exception of steep bluffs along the Lake Michigan shoreline.

The city contains portions of six major watersheds:

- Kinnickinnic River
- Lake Michigan Direct-Drainage
- Menomonee River
- Milwaukee River
- Oak Creek
- Root River

Figure B: PERCENTAGE OF CITY AREA BY WATERSHED



The watersheds can be observed in relation to the city's geography in Map A: Milwaukee Watersheds in the Appendix. Figure B depicts the percentage each watershed contributes to the total area in the city.

All of the watersheds are ecologically unique and are located in environments with varying degrees of urbanization. Because of this, areas of certain watersheds have been more severely impacted due to past alterations to increase stormwater runoff removal and control flooding, such as channelization and/or dam installation.

IMPERVIOUS SURFACES

Impervious surfaces are those composed of any material which impedes or prevents the natural infiltration of water into the soil, such as concrete, asphalt, dense gravel, or compacted soils. Examples of impervious surfaces include streets, sidewalks, roofs, patios, and parking lots.

These surfaces contribute significantly to increased volumes of stormwater runoff, particularly during major storm events. City regions with high percentages of impervious surface area are at increased risk for localized flooding, high stormwater flow into the sewers, and basement backups, as the precipitation has few opportunities to infiltrate the soil. In addition, impervious surfaces channel flow towards grey infrastructure (*e.g.* gutters, storm sewers) which results in faster accumulation and larger volumes of stormwater than would occur in natural settings with higher permeability.

Impervious Surface Area Calculation Methods

Parking and Airports

Parking lots represent a considerable percentage of the total impervious surface in the City of Milwaukee. While providing adequate customer parking is a necessity for businesses to compete and grow, the vast areas of land covered with concrete and asphalt to create paved lots present an environmental challenge in managing stormwater. Calculating the surface area currently occupied by impervious parking lots will allow planners to identify high priority locations where permeable paving may be implemented with the objectives of reducing impervious surface, increasing the quantity of green infrastructure, and decreasing contaminants in runoff.

The total area of impervious parking lot surface was calculated by utilizing the "Polygon Identify" tool in Map Milwaukee Green Infrastructure Planning map. Sections of the city were isolated with the tool and the area calculation was set to "acres" with results displaying for the Impervious Parking layer. The data was converted to .CSV files and imported to an Excel spreadsheet, where specific measurement regions were cataloged and the data analyzed to determine the total area of all parking for the city.

This process was then repeated for the same location subsets while accounting for the area of Impervious Parking and filtered by government property to return results for public parking lots. The total for the public parking was then subtracted from the overall total to attain the area for private lots. The area subsets were also analyzed for percentage inclusion in each watershed, so that the parking data was further broken down by acreage in each watershed zone.

MMSD provided the GIS mapping layer for impervious parking, which was developed as part of the *RGIP*. Although the accuracy of the data was sufficient for regional planning purposes, more accurate information is required for the municipal planning level. This data has been incorporated into the *GIBI* report, but will be corrected and revised immediately following replacement of the layer with more accurate data.

Structures

There are a wide variety of structure types represented in the city of Milwaukee, including, but not limited to, single- and multi-family residences, condominiums, schools, retail businesses and shopping centers, office buildings, manufacturing and industrial complexes, and municipal buildings. The impervious structure results may be used to estimate the quantity of area available for implementation of green roofs and rainwater catchment devices (cisterns) as means to lower overall impervious surface area.

As with the parking impervious area, the total area for all structures was calculated utilizing the Polygon Identify tool. Zones of the city were identified and measured for acres in Impervious Structure layer; data was converted to a .CSV and exported to Excel spreadsheets for analysis and area computation. The subsets were again also analyzed by watershed.

Public Structures were filtered by government properties and foreclosures owned by the city to obtain publicly-owned impervious structure area. This was again subtracted from the overall total to procure total area for private property.

According to the procedures used by MMSD in quantifying impervious structure area for their service area, multipliers were implemented to account for extraneous imperviousness related to different structure types. The multiplier utilized for all structure types to account for improvements such as residential patios, garages, and walkways, business walkways, driveways, and miscellaneous buildings was 30%. Therefore, 30% was applied to the raw data for all structure types to achieve the total area for the city and in each watershed.

Once again, the subsets were analyzed for percent inclusion in each of the six watersheds. This allowed for calculation of impervious structure area by watershed.

Public Infrastructure

Streets, alleys, and sidewalks constitute the largest percentage of all the impervious surface types within the City. Public infrastructure, therefore, contains the greatest opportunity to increase the quantity of green infrastructure as well as reduce overall impervious surface area.

The surface areas of public city streets, alleys, and sidewalks were obtained directly from the Department of Public Works.

Total surface areas of county trunk highways, state highways, national highways, and interstate highways within city limits were calculated from measurements made utilizing the "Measure Distance" tool in GIS Map Milwaukee Green Infrastructure Planning aerial photo map. Lengths and widths of all sections of these street types were cataloged and analyzed in Excel spreadsheets to create a comprehensive dataset for each highway in each of these categories. On- and off-ramps, shoulders, turn lanes, and other additional features were all included in the analysis.

As per procedures performed by MMSD to account for sidewalks, driveways and aprons, a 15% multiplier was

incorporated into results for all except interstate highways. As DPW data included sidewalk area, a 5% multiplier was used to account for driveway aprons. The resulting surface areas should best approximate the total or impervious public infrastructure. However, ongoing and future construction projects may affect total calculated surface areas.

In addition, the locations and segments were separated by watershed to determine total impervious infrastructure surface area for each of the six watersheds.

Impervious Surface Area Results

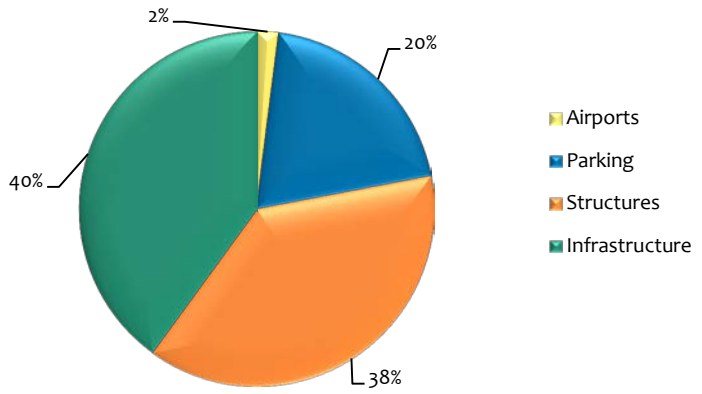
Analysis of the four categories, for the city as a whole, shows that 45.5% of Milwaukee is covered with impervious surface. Table 2 shows the breakdown in total area (acres) for each impervious surface type.

Table 2: INVENTORY OF IMPERVIOUS SURFACES IN MILWAUKEE CITY LIMITS

IMPERVIOUS SURFACE TYPE	CATEGORY	AREA IN ACRES	PERCENT OF CITY AREA
PARKING	Public	992	1.6
	Private	4,637	7.5
AIRPORTS	Airport	592	1.0
STRUCTURES	Public	928	1.5
	Private	9,734	15.8
PUBLIC INFRASTRUCTURE	City Streets, Alleys, & Sidewalks	9,108	14.9
	County Trunk Highways	313	0.5
	State Trunk Highways	723	1.2
	National Highways	311	0.5
	Interstate Highways	637	1.0
TOTAL		***27,975***	***45.5***

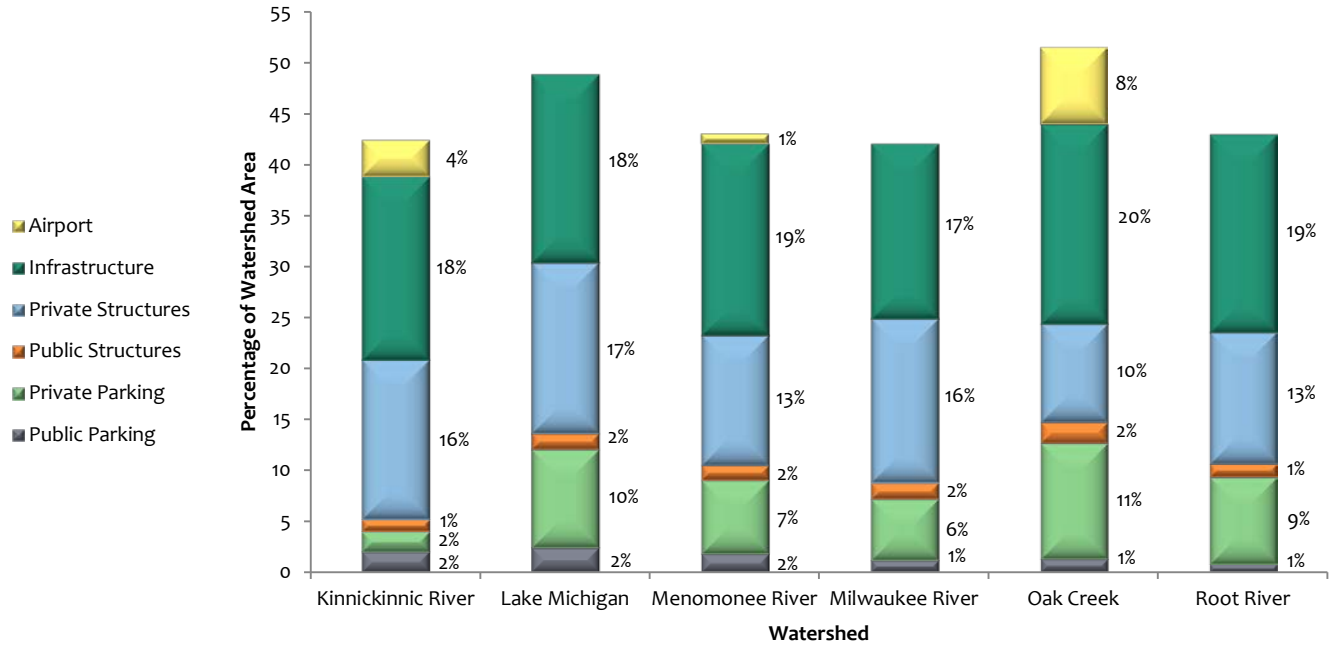
The total citywide impervious surface area was further analyzed to attain the percentage attributed to each type of impervious surface, as seen in Figure C. Results show that public infrastructure and structures comprise the majority of impervious surface area within city limits, while parking lots also make up a significant percentage of surface area.

Figure C: PERCENTAGE OF IMPERVIOUS SURFACE AREA BY TYPE



The data was also analyzed for the percentage of impervious surface type for each watershed, and the results are presented in Figure D. This calculation involved dividing the area (in acres) for each impervious type by the area (in acres) of each watershed. This resulted in the percentage of watershed area for each type of impervious cover as well as the collective total percentage for each watershed.

Figure D: PERCENTAGE OF IMPERVIOUS SURFACE TYPES FOR EACH WATERSHED



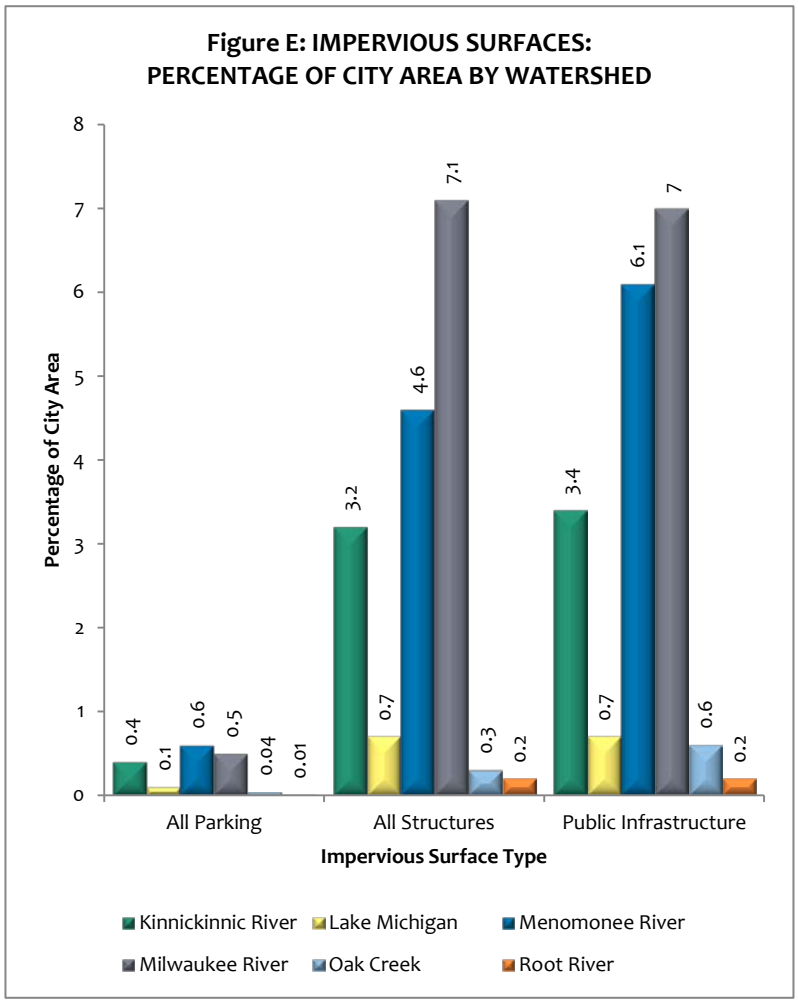
Of the six watersheds, Oak Creek has the highest percentage of its area, 52%, covered with impervious materials within Milwaukee city limits. The Lake Michigan watershed has the second highest percentage of total impervious cover at 49%.

The impervious surface percentage totals for the remaining four watersheds are as follows: Menomonee River with 44%, the Root River with 43%, Kinnickinnic River at 43%, and the Milwaukee River with 42% of its area covered by impervious surface. Note: the table results have been rounded to the nearest 1% for clarity.

Additional analysis was performed to determine the percentage of total city area of parking lots, all structures, and public infrastructure for each watershed. These results are depicted in Figure E on page 16.

The outcome of this calculation shows that the largest percentage of city area is covered by impervious surfaces in the Milwaukee and Menomonee River watersheds. The impervious cover in the Kinnickinnic River watershed also represents a significant proportion of the overall city area.

Lake Michigan Direct-Drainage, Oak Creek, and the Root River all contribute slightly to the city's total impervious area, but to a much lesser extent.



Analysis of the GIS maps depicting topography, combined sewer area, and basement water infiltration reports for the years 2008-2010 (Maps B, E, and F in the Appendix) do not show a very strong correlation between basement water infiltration and the combined sewer region. In fact, some of the locations with the highest percentages of impervious surface in the combined sewer region have the lowest reports of basement flooding and backups, such as the areas north and west of the Milwaukee River downtown.

The region of the city with the highest concentration of basement flooding and backups is in the northwest and bordered by Silver Spring Drive to the north, Green Bay Road and Martin Luther King, Jr. Drive to the East, North Avenue to the south, and North 91st Street to the west. Detailed maps of reports for basement water infiltration and topography in this area are shown in the Appendix, Maps G and H.

At this time, the impervious layer data has been removed from the Green Infrastructure Planning Tool GIS map; consequently there is not a way to compare the percentages of impervious surface to basement water infiltration reports for this region.

SHORELINES

Natural shorelines with adequate buffer zones are valuable resources in decreasing stormwater runoff, enhancing soil infiltration, reducing water pollution, and protecting against erosion. Conversely, missing or deficient buffers and/or concrete channelization can exacerbate localized flooding, diminish infiltration, and increase pollution due to runoff.

A comprehensive inventory of shorelines was completed to ascertain the total length (in linear feet) of riverbanks, lakes and ponds, and drainage ways within the City of Milwaukee. Analysis includes the total length of all waterways and shorelines, as well as cataloging the composition of the shoreline, *e.g.* whether the shoreline possesses natural vegetative buffer zones or has been channelized with concrete.

Shoreline Length Calculation Methods

Rivers, Streams, Creeks, and Drainage Ways

The measurements for these water bodies were completed using the GIS Map Milwaukee Green Infrastructure Planning aerial photo map. The "Measure Distance" tool was utilized to measure lengths (in feet) of segments, for which the boundaries and data were recorded in an Excel spreadsheet. The segments were analyzed for total length, length of shoreline with adequate natural buffer zones, length of natural shoreline without adequate buffers, and the length of concrete channels. This data was further evaluated to establish shoreline statistics for each of the six watersheds.

Ponds and Lakes

The shoreline measurements for ponds and lakes were accomplished utilizing the "Measure Distance" tool in the GIS Map Milwaukee Green Infrastructure Planning aerial photo map. The shoreline perimeters were measured in feet, and then recorded by location and watershed in an Excel spreadsheet.

Lake Michigan's shoreline was also analyzed using the "Measure Distance" tool. The shoreline length was measured and shore/buffer type cataloged; results were recorded in an Excel spreadsheet.

Shoreline Measurement and Classification Results

River, Stream, Creek, Drainage Way, Lake, and Pond Shorelines

The shoreline results, separated by type and watershed, are summarized in Table 3 on page 18.The riparian shoreline measurements yield a total of 676,053 linear feet (128 miles) of shoreline. This result includes measurement of both sides of the bank; therefore actual length of rivers and streams in Milwaukee equals 338,026.5 linear feet (64 miles). The same holds true for drainage ways. There are 55,366 linear feet (10.5 miles) of drainage shoreline within the City, which converts to 27,683 feet (5.25 miles) of actual drainage ways.

Table 3: LINEAR FEET OF SHORELINE BY WATERSHED								
	SHORELINE AND BUFFER TYPE:							
	Rivers, Streams, Creeks*:			Drainage Ways:	Lakes and Ponds:			
WATERSHED:	*NATURAL WITH BUFFER ZONE*	*NATURAL, LITTLE/NO BUFFER ZONE*	*CONCRETE CHANNEL*	*NATURAL (GRASS, GRAVEL)*	*NATURAL (SAND, ROCKS) WITH BUFFER ZONE*	*NATURAL, LITTLE TO NO BUFFER ZONE*	*CONCRETE*	**TOTAL**
KINNICKINNIC RIVER	34,380	15,276	114,307	9,201	360	10,249	0	**183,773**
LAKE MICHIGAN	0	0	0	0	28,691	0	35,842	**64,533**
MENOMONEE RIVER	147,012	75,552	78,835	0	5,928	6,583	0	**313,910**
MILWAUKEE RIVER	31,653	113,629	55,607	2,685	6,644	36,917	0	**247,135**
OAK CREEK	625	9,177	0	43,480	0	0	0	**53,282**
ROOT RIVER	0	0	0	0	0	0	0	**0**
TOTAL	**213,670**	**213,634**	**248,749**	**55,366**	**41,623**	**53,749**	**35,842**	**862,633**

*Measurement of these water bodies includes both sides of bank; actual length of bed would be half of this total.

Figure F: SHORELINES - PERCENTAGE OF TOTAL BY TYPE

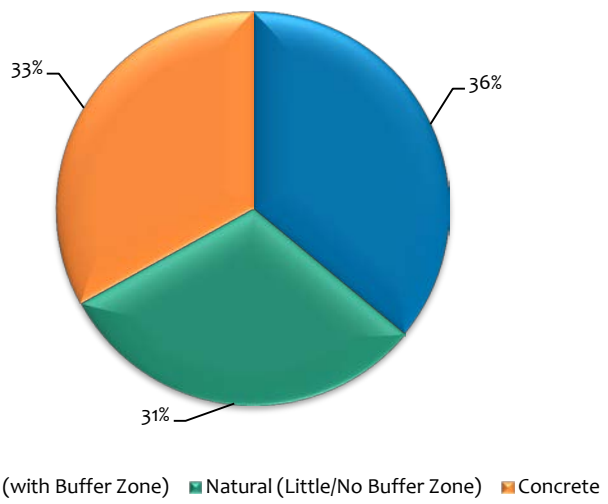


Figure F represents the percentage of each type of shoreline category within Milwaukee's city limits. All types of shoreline, *i.e.* rivers, streams, creeks, drainage ways, ponds, and lakes, are included in this calculation. The results highlight the large quantity of concrete shore, 1/3 of the total, which could theoretically be removed and restored to a more natural state.

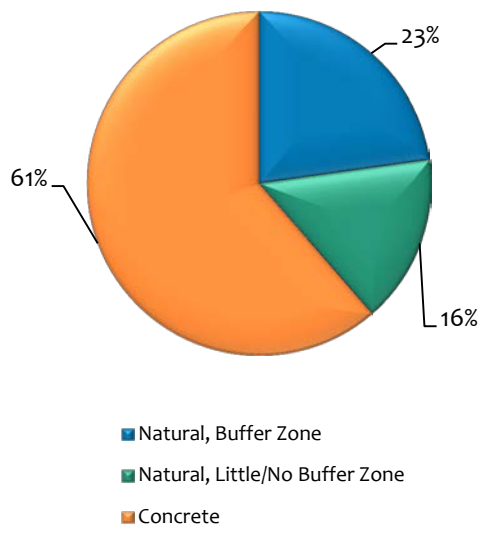
Also noteworthy is the significant length of shoreline with little to no natural buffer zone present where there a considerable opportunity for restoration also exists.

Lake Michigan Shoreline

Measurement of Lake Michigan's shoreline yields a total length of 58,277 linear feet (11.04 miles). The shore type classifications and lengths of each type can be seen in Figure 6. Sandy beaches and shoreline length with wide buffer zones were tallied independently from rocky shoreline with very little to no buffer zones. Piers and man-made concrete shorelines were classified separately. Breakwalls not connected to the shoreline were not included in the measurement data.

Figure G highlights the percentage of each type of shoreline for Lake Michigan. The overall measured length of Lake Michigan's shoreline is 58277 linear feet (11 miles), with 13,188 feet (2.5 miles) of natural shoreline with sufficient buffer; 9,247 feet (1.75 miles) of natural shoreline lacking buffers; and 35,842 feet (6.8 miles) of concrete-lined shore within city limits.

Figure G: PERCENTAGE OF LAKE MICHIGAN SHORELINE BY TYPE



EXISTING GREEN INFRASTRUCTURE

The Water Chapter of the *ReFresh Milwaukee* sustainability plan proposes targets for the implementation of green infrastructure BMPs in the city. Beginning in 2014, the volume of stormwater captured by green infrastructure is to increase by 10% annually. The Plan also requires an inventory of green infrastructure BMPs currently operational in Milwaukee.

Existing green infrastructure BMPs are categorized in the following manner for quantification purposes:

- Bioretention (includes bioswales and rain gardens)
- Constructed Wetlands
- Green Roofs
- Native Landscaping
- Porous Pavement – includes porous concrete, porous asphalt, porous pavers
- Rain Barrels
- Rainwater Catchment (Cisterns)
- Soil Amendments
- Stormwater Trees

Existing Green Infrastructure Inventory Calculation Methods

A comprehensive directory for all green infrastructure BMPs presently installed in the city did not exist prior to this report. Therefore, many different resources were employed in an attempt to identify and quantify all green infrastructure projects. Listed below are the sources utilized to locate, measure, and categorize as many green infrastructure BMPs as possible. A caveat to this inventory is that any BMPs constructed on private property, or which have not been reported to any of the sites or sources below, have not been counted.

Sources employed in the GI BMP inventory process were:

- *Milwaukee Journal-Sentinel* archives
- Greenroofs.com (Green Projects database)
- LiveRoof.com (Milwaukee projects)
- City of Milwaukee Department of Public Works – Stormwater Management Office
- MMSD Green Infrastructure Grant Application database
- H2O Capture website – database of self-reported GI BMP implementation
- Google – acquired names of landscapers who installed green roofs
- Use of GIS Map Milwaukee Green Infrastructure Planning map to measure area of green roofs in two projects where data was unavailable
- Personal visit to one green roof to measure area

Capture volumes for green infrastructure BMPs vary widely depending on type. Table 4, page 21, depicts the estimated capture capacities and area of impervious surface managed for each type of green infrastructure BMP. This information has been adapted from MMSD's *Regional Green Infrastructure Plan*, Table 3, page 30.

Table 4: ESTIMATED STORMWATER PERFORMANCE CAPACITIES BY GREEN INFRASTRUCTURE STRATEGY[1]				
Green Infrastructure Strategy	**Unit of Measure**	**Potential Storage Capacity (gallons)[2] per SF**	**Potential Storage Capacity (Gallons) per 1000 SF Strategy Implementation**	**Expected Impervious Surface Area (SF) Managed per 0.5-inch Rainfall per 1000 SF (or unit) Strategy Implementation**
BaseTern[3]	Each	2400-7000[4]	31,600 each	101,000
Bioretention, Bioswales, Greenways	Square foot (SF)	3 – 7.5[5]	7500	1200
Cisterns	Each	1000[6]	1000[6]	3,200
Green Roofs	SF	1	1000	100
Native Landscaping[5]	SF	.4	400	N/A
Porous Pavement	SF	3[7]	3000	400
Rain Barrels	Each	55[6]	55[6]	175
Rain Gardens	SF	4.4	4400	1200
Soil Amendments[8]	SF	0.2	200	N/A
Stormwater Trees	Each	25[9]	25[9]	80[10]

[1] Green alleys, streets, and parking lots are made up of other green infrastructure strategies. The wetlands strategy is encouraged but not quantified here. Calculations based on 0.5 inch rainfall on impervious surfaces.
[2] Potential physical storage capacity per half-inch rainfall.
[3] BaseTern (Basement cistern)
[4] Potential storage capacities range from 2400 gallons per 1 foot (ft) of depth for stone fill (33% void space) to 7000 gallons per 1 ft of depth for stormwater harvesting cells (95% void space).
[5] Storage capacity per 1 ft of depth of storage media; dependent upon whether storage occurs above media (100% void space) or within media (30-40% void space).
[6] Storage capacity is 1 gallon per 1 gallon volume physical size (*e.g.*, 1000 gallon cistern captures 1000 gallons rainfall).
[7] Storage capacity is per 1 ft of depth of storage media.
[8] Capacities for native landscaping and soil amendments are based on Natural Resources Conservation Service runoff curve number changes during a 2-inch rainfall.
[9] Each stormwater tree has potential capture of 25 gallons.
[10] Each tree manages 80 SF of impervious area.

Existing Green Infrastructure Inventory Results

The inventory of known, existing green infrastructure strategies in the city provides a baseline measure as to the current stormwater runoff capture volume and quantities of green infrastructure presently in use. From here, City planners and leaders will be able to plan for increases in green infrastructure implementation and gauge progress in meeting the stormwater capture goals.

Table 5, below, is an analysis of known existing green infrastructure strategies located within Milwaukee city limits. Of note: only existing strategies that are documented have been included here; there are most likely many more BMPs in use in the city, but if they are undocumented, they were unable to be counted in the inventory. The table is separated by BMP type, and includes potential stormwater capture volumes based on information contained in Table 4 on page 21.

Table 5: INVENTORY OF CURRENT & KNOWN GREEN INFRASTRUCTURE IN CITY OF MILWAUKEE

TYPE	NUMBER	TOTAL AREA (SF)	TOTAL AREA (ACRES)	TOTAL GALLONS OF CAPTURE[1]
Bioretention[2]	231	894,418	20.5	7,263,957
Constructed Wetlands	2	15,360	0.4	127,488
Green Roofs	100	603,580	13.9	603,580
Native Landscaping	14	211,717	4.9	84,687
Porous Pavement	53[3]	568,136	13	2,577,908
Rain Gardens	32	71,550	1.6	314,823
Rain Barrels	5,529[4]	N/A	N/A	304,095
Rainwater Catchment (Cisterns)	52	N/A	N/A	2,719,369
Soil Amendments	0	0	0	0
Stormwater Trees	395	N/A	N/A	9,875
TOTALS		**2,364,761**	**54.3**	***14,005,782***

[1] Actual BMP engineering design capture data was used where available; otherwise, potential capture was calculated from guidelines as shown in Table 4, Estimated Stormwater Performance Capacities by Green Infrastructure Strategy, on page 21.
[2] Includes bioswales.
[3] Exact number unknown due to sidewalk and sidewalk/driveway projects that were not counted individually by DPW.
[4] Exact number is unknown; data estimated from MMSD based on rain barrels sold in MMSD service area and H2O Capture self-reporting.

There were no records found pertaining to the implementation of soil amendments during the course of research into existing green infrastructure strategies. However, soil amendments may have been implemented, but as the projects were either not reported or done on private land, they are unable to be verified and incorporated into this inventory. Consequently, the value listed in Table 5 is zero. In addition,

MMSD has data on the quantity of rain barrels that have been sold and distributed in the entire service area, but not exclusively for the city. Therefore, this data was determined based upon the city's area relative to the service area (23.4%), and the resulting number was added to that for rain barrels self-reported to H2O Capture.

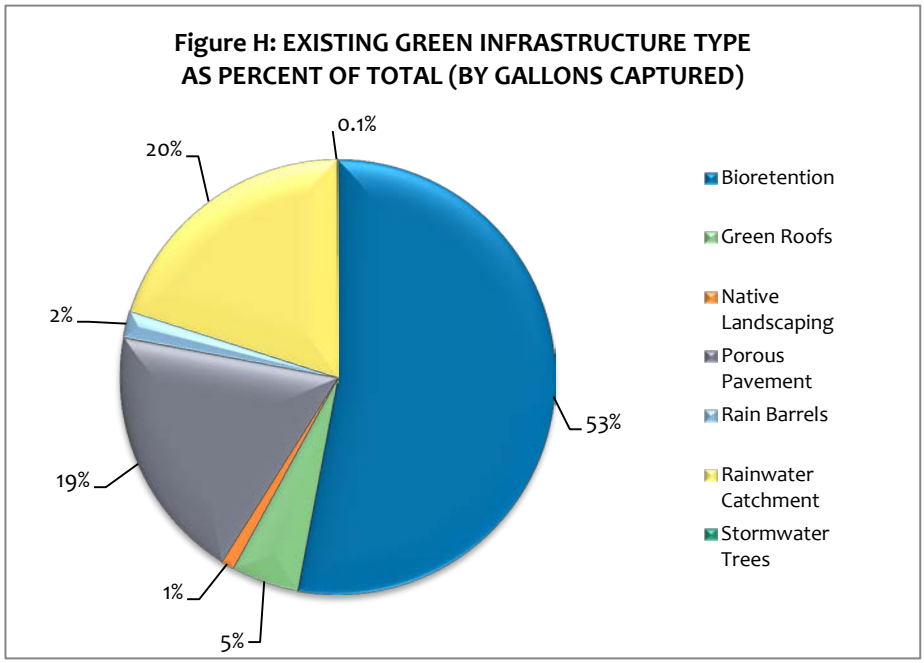


Figure H depicts the types of existing BMPs as a percentage of those in place in the city, based on total gallons of capture. The value for bioretention includes bioswales, rain gardens, and constructed wetlands. The value for soil amendments is zero, based on the lack of available data regarding implementation, and as such is not included in the chart. The value for stormwater trees equals 0.1%, which is too small to be apparent on the chart.

REFRESH MILWAUKEE IMPLEMENTATION TARGETS

The Water Chapter of *ReFresh Milwaukee* and MMSD's *RGIP* propose significant investment in green infrastructure and are innovative approaches to stormwater management in an urban environment. Attaining the objectives outlined in the Plans would require substantial planning and design in order to maximize economic and runoff capture efficiencies.

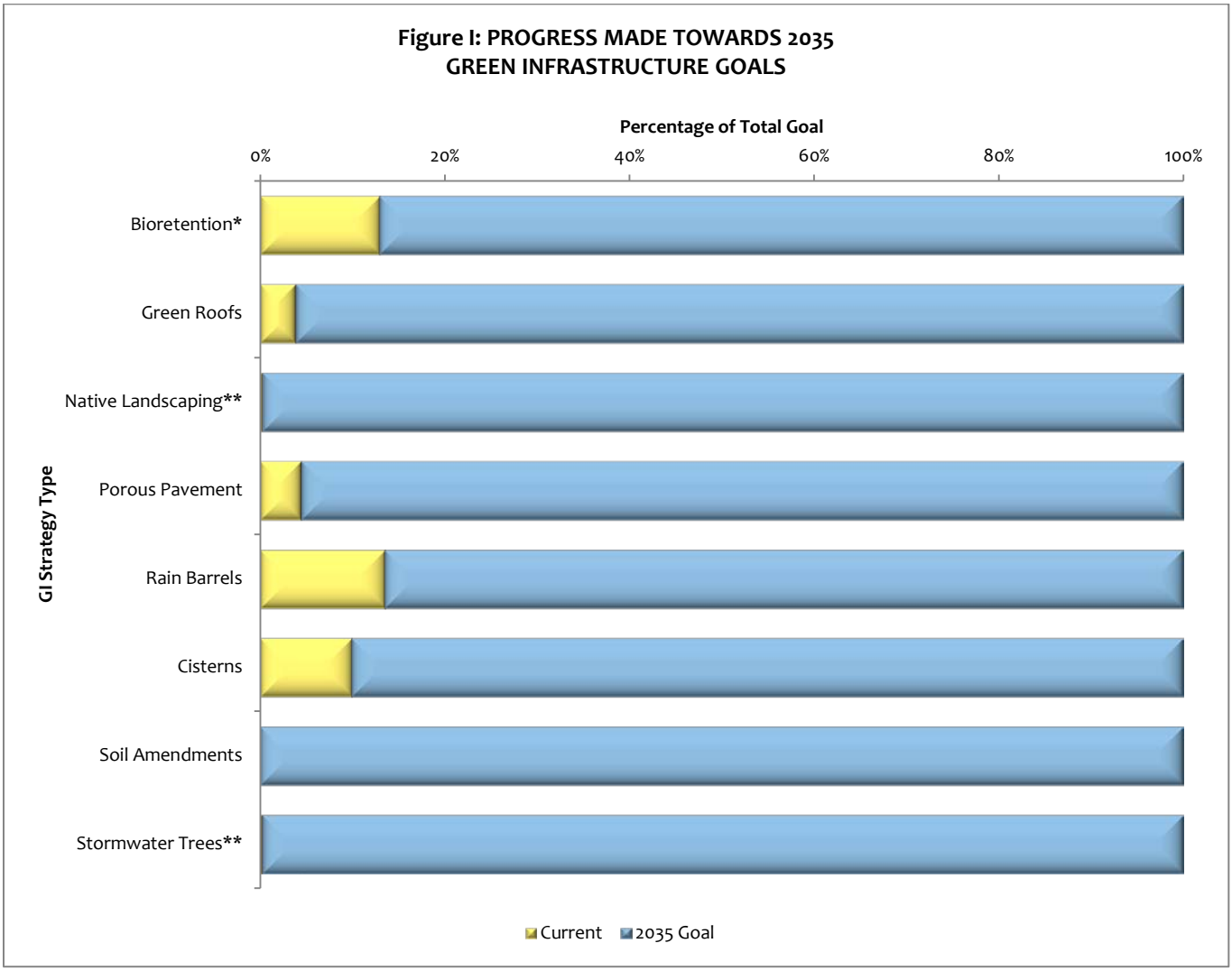
Table 6 details examples of specific quantities and areas of green infrastructure BMPs that would be necessary to fulfill the goals set forth in the *RGIP*. The quantities for each BMP type included in the table have been adapted from MMSD's *RGIP*, and are intended to be used for illustrative purposes. The City's forthcoming Green Infrastructure Plan will determine what strategies, and quantities of each, Milwaukee will pursue to achieve its (as yet undetermined) targets.

Table 6: EXAMPLES OF STRATEGIES NECESSARY TO ACHIEVE MMSD'S GREEN INFRASTRUCTURE GOALS (2014 – 2035)*

Green Infrastructure Strategy	Current Inventory	2035 Goal	Equivalent Quantity	Total Needed to Reach Goal	Annual Total Needed to Reach Goal	Annual Equivalent Quantity Needed to Reach Goal
Bioretention, Bioswales, Constructed Wetlands, Rain Gardens	22.5 Acres	152 Acres	44,432[1]	129.5 Acres	6 Acres	1791[1]
Green Roofs	14 Acres	349 Acres	3,041[2]	335 Acres	16 Acres	139[2]
Native Landscaping	4.9 Acres	2,012 Acres	398[3]	2007 Acres	96 Acres	19[3]
Porous Pavement	13 Acres	278 Acres	2411[4]	265 Acres	12.5 Acres	115[4]
Rain Barrels	5,529 Barrels	35,568 Barrels	-----	30,039 Barrels	1,430 Barrels	-----
Rainwater Catchment (Cisterns)	52 Cisterns[5]	473 Cisterns[5]	-----	421 Cisterns	20 Cisterns	-----
Soil Amendments	0 Acres	3,557 Acres	679[6]	3,557 Acres	169 Acres	32[5]
Stormwater Trees	395 Trees	172,692 Trees	-----	172,297	8,204 Trees	-----

* Goals adapted from the MMSD *Regional Green Infrastructure Plan*; Quantities needed are estimated based on years 2015-2035 as 2014 strategies have been counted in the Current Inventory totals.
Assumptions regarding quantities for each GI strategy:
[1] Number of strategies at 150 SF each
[2] Number of buildings with new 5000 SF green roof
[3] Number of city blocks with native landscaping
[4] Number of city blocks with 25% porous pavement
[5] Number of cisterns in buildings with 6500+ SF roof
[6] Number of city blocks with soil amendment

Figure I reflects the City's current progress, including strategies planned and/or constructed in 2014, relative to MMSD's 2035 estimated target. If Milwaukee adopts the MMSD goal of capturing 173 million gallons of stormwater, this chart illustrates how much additional green infrastructure would need to be implemented to achieve that goal.



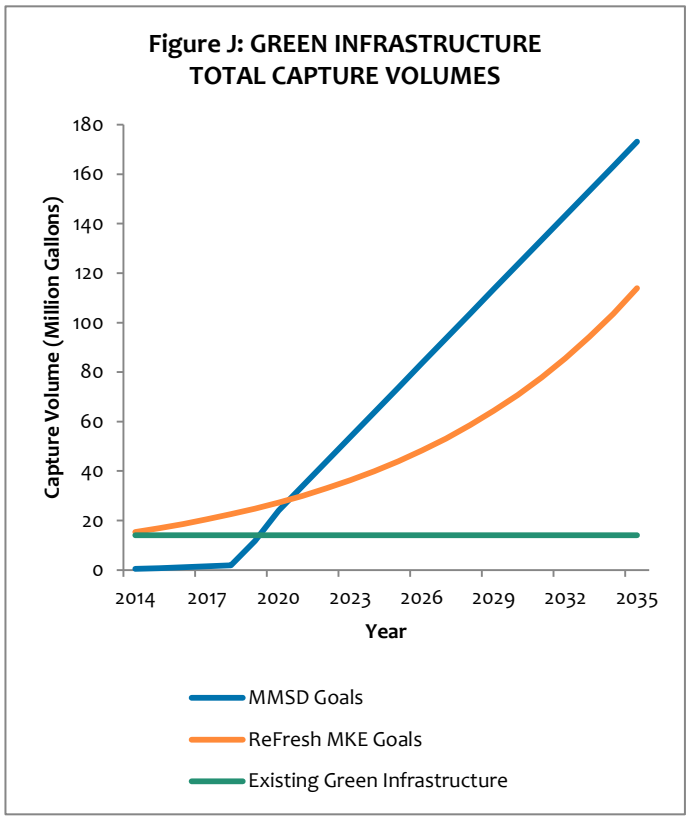
*Includes bioswales and rain gardens
**Current quantities (including those planned/constructed in 2014) are included here, but are a very small percentage of the total goal, so are not registering on the chart.

As evidenced by the table above, there is significant progress to be made if Milwaukee were to adopt MMSD's proposed stormwater targets.

While the current quantities and capture capacities of existing green infrastructure strategies are considerable, the City's commitment to, and investment in, green infrastructure must also be enduring and strong if full implementation of *ReFresh Milwaukee*'s objectives, or those of MMSD if adopted, is to occur.

Figure J, page 26, depicts the total stormwater volumes captured by green infrastructure strategies for 1) the City's pro-rated portion of MMSD's *Regional Green Infrastructure Plan*; 2) goals proposed by the *ReFresh Milwaukee* sustainability plan; and 3) quantities from existing green infrastructure. This graphic highlights the differences between how much green infrastructure the City would need to implement to achieve the

targets set forth by both MMSD and *ReFresh Milwaukee*.



The MMSD Goals series represents the green infrastructure capture volumes the City would need to meet if it adopted the pro-rated (based on percentage of MMSD service area) capture volumes stipulated in the *Regional Green Infrastructure Plan*, which would be 23.4% of 740 million gallons, or 173 million gallons.

The *Refresh Milwaukee* goals show the volumes that result from the goal of increasing the volume of stormwater runoff captured by 10% annually, beginning with the current baseline of 14 million gallons of current capture.

The Existing Green Infrastructure series depicts the totals for existing private and public projects that are currently operational and for which capture volumes have been confirmed. See Table 5 on page 22, for more details.

PROJECTS AND REDEVELOPMENT: GREEN INFRASTRUCTURE OPPORTUNITIES

Milwaukee is taking an active role in driving redevelopment at several sites in the city. As the majority of these locations also possess a large amount of impervious surface and industrial structures, the opportunities available to implement a wide array of green infrastructure strategies are great. Not only will these projects increase the amount of green infrastructure functioning in the city, but also reduce the vast quantities of impervious surfaces present in these areas. While most of the green infrastructure BMPs have not yet been fully planned, designed, or built, general information regarding proposed installations is included when available. For the remaining projects, general estimates have been made to give rough numbers regarding potential stormwater capture volumes.

Milwaukee's Green Streets

Sustained investment in Green Streets strategies is a current City priority. Projects for 2014 have been identified and designed and are included in the Existing Green Infrastructure Inventory. As identification of reconstruction paving projects that may be eligible for Green Streets strategies in upcoming years is still underway, calculating future potential green infrastructure capture volumes to apply towards stormwater capture targets is not feasible at this time. The average annual repave/reconstruction projects involve approximately 17 miles of streets and 2.5 miles of alleyways. Utilizing the average percentage of past Green Streets strategy implementation versus the miles of roadway repaved, rough estimates may be devised for potential future BMP implementation, as observed in Table 7.

Table 7: POTENTIAL STORMWATER CAPTURE FROM FUTURE GREEN STREETS STRATEGIES IMPLEMENTATION

Type	Estimated Annual Area (Acres)	Estimated Annual Storage Volume (Gallons)	Estimated Total Area, 2014-2035 (Acres)	Estimated Total Storage Volume, 2014-2035 (Gallons)
Bioretention/Bioswales	0.5	164,250	10.5	3,449,250
Porous Pavement (Parking)	0.14	18,295	2.9	384,195
Porous Pavement (Sidewalks/Driveways)	0.22	28,750	4.6	603,750
Porous Pavement (Alleys)	0.88	115,200	18.5	2,419,200
TOTAL	**1.74**	**326,495**	**36.5**	**6,856,395**

This table does not represent any actual green infrastructure BMPs that are either planned or scheduled to be installed by the City's Department of Public Works. Rather, it is a conservative estimate based on current and historical BMP implementations as part of the *Green Streets Stormwater Management Plan*. Definitive designs and plans for each year going forward are not finalized until that year's budgets are approved in the fourth quarter of the previous year. Future implementation may be greater than the estimates given above.

Full implementation of Green Streets strategies, *i.e.* if all scheduled paving and construction/reconstruction projects included some manner of green infrastructure BMP installation, could potentially yield significant stormwater runoff flow reduction, increased capture volumes, and substantial decreases in TSS and great strides in meeting future TMDLs.

The Green Corridor

Milwaukee's Green Corridor is located on South Sixth Street between Howard Avenue and College Avenue in the 13th Aldermanic District (the "Garden District"). The Green Corridor designation refers to the continuing commitment to achieve common sustainability goals that improve environmental performance, attract business development, raise public awareness, and support regional growth. The Green Corridor functions as a showcase for green technology and innovation.

Projects highlighted along the Green Corridor include a community-organized and –operated garden, the Energy Exchange: a forum for neighborhood sustainability, multiple green infrastructure BMPs designed to reduce stormwater runoff, and enhanced landscaping and beautification. Stormwater is managed along the Green Corridor through the use of bioswales, porous pavement, and native plantings.

Milwaukee hopes to be able to replicate the Green Corridor model in other locations in the city, both in conjunction with the Green Streets plan and as stand-alone projects, as part of future development.

The 30th Street Industrial Corridor

The 30th Street Industrial Corridor is a major industrial zone consisting of 880 acres of land in the city. The area is bordered by West Hampton Avenue to the north, North 27th Street to the east, West Highland Boulevard to the south, and North 35th Street to the west. Milwaukee is in the midst of a collaborative effort to transform the area into a major economic hub and employment center for the city.

Redevelopment opportunities lie primarily in underutilized industrial sites, which contain substantial quantities of impervious surface. Implementation of sustainable green infrastructure strategies will aid the City in meeting state water quality objectives as well as spur economic development. Designs for the North Corridor focus mostly on construction of detention basins, with a total storage volumes of approximately 32 million gallons for the recommended alternative plan; however, these will not count towards green infrastructure targets.

The plan for the South Corridor includes a range of green infrastructure projects with a future potential total storage capacity of 19.5 million gallons:

- 50 acres of porous pavement
- 26 acres of bioretention/bioswales
- 329 acres of native landscaping
- 60 acres of green roofs
- 9 stormwater trees per city block
- 88 cisterns
- 5863 rain barrels
- 613 city blocks with soil amendments

Full implementation of the proposed green infrastructure BMPs in the South Corridor could contribute greatly to the City achieving its overall capture targets when they are ultimately adopted.

Milwaukee's Inner Harbor Redevelopment

The Inner Harbor is a 970-acre site located south of downtown Milwaukee and is bordered roughly by National Avenue to the north, the Kinnickinnic River to the south, and South First Street to the west. Redevelopment activities between private and public partners are aiming to revitalize the waterfront and surrounding neighborhoods.

The *ReFresh Milwaukee* sustainability plan addresses the Inner Harbor redevelopment and identifies two targets that pertain to stormwater:

- Protect and revitalize 10 acres of shoreline habitat in design or completed stage by the end of 2014.
- Net-zero stormwater runoff in the study area by 2023.

Remediating brownfields, restoring a 10-acre wetland, and installing a variety of green infrastructure strategies have all been proposed for inclusion during redevelopment of the site. This project is still in the initial planning stage; therefore, information is not yet available regarding actual green infrastructure strategies that will be implemented.

The Reed Street Yards and Global Water Technology Park

The Reed Street Yards is a mixed-use urban office, educational, research and technology zone focused on the international water industry. In time, the park will house more than one million square feet of facility space and be the physical hub and brain of an international water cluster. It is a 17-acre property, bordered by the South Menomonee Canal and West Seeboth Street to the north, Third Street to the east, Oregon Street to the south, and the Sixth Street Viaduct to the west.

Reed Street Yards is one of the first Eco-Industrial Parks in Wisconsin and seeks to balance natural resources with economic development. Due to this designation, sustainability and green infrastructure are a primary focus. Green infrastructure strategies to be implemented include porous pavement, bioswales, green roofs, and purple piping for water recycling purposes. The initial phase of green infrastructure projects includes porous paving in the parking lanes along Freshwater Way and 2,200 square feet of bioretention. These strategies are included in the current BMP inventory list in Table 5 on page 22.

Additional projects are in the planning stages and will be brought on line as the redevelopment progresses on the Reed Street Yards. These green infrastructure projects will be included in the inventory as they are implemented.

BaseTern™ Stormwater Catchment Pilot Program

Milwaukee's development of the BaseTern™ is an innovative and cost-effective approach to managing stormwater runoff and aims to help neighborhoods be more resilient to extreme storm events. BaseTerns™ are underground stormwater management or rainwater harvesting structures that have been created from basements of former houses which have been slated for demolition.

Vacant, City-owned foreclosures, located in neighborhoods with high prevalence of localized flooding and basement backups, are evaluated for several parameters prior to consideration for the BaseTern™ program.

For properties meeting the relevant criteria, the existing house would be razed and the basement utilized as a cistern. Porous fill material (coarse gravel or stormwater harvesting cells, for example) may be inserted into the basement void space along with the installation of a permeable layer of soil to cover the system and add a level of public safety.

Analysis of the structure by an engineering firm during the initial phases determined that each BaseTern™ is capable of capturing upwards of 30,000 gallons of water, depending on size of the foundation structure and the porosity of any fill material used.

The focus of this approach is to reuse the basement as a cistern to harvest rainfall from adjacent structures and/or stormwater from impervious surfaces on surrounding properties. The collected water may be recycled to irrigate community gardens or allowed to infiltrate into the soil. Benefits of this pilot program include collection of stormwater that may otherwise cause flooding issues, reduced clear water flow to sewers, increased soil infiltration and groundwater recharge, higher quality runoff due to reduced loading of TSS and other pollutants, and providing water for reuse by community gardens.

Although the BaseTern™ technology is not specifically mentioned in the MMSD *RGIP*, it may become a viable method for achieving the City's stormwater capture goals in light of the urban real estate constraints.

Strong Neighborhoods Plan and HOME GR/OWN Initiative

At the present time, the City of Milwaukee owns over 1,000 foreclosed homes and approximately 2,700 vacant lots, which are an economic drain on taxpayers and contribute to further neighborhood destabilization. Mayor Barrett's Strong Neighborhoods Plan helps to preserve housing stock and stabilize neighborhoods through a comprehensive approach: prevention, mitigation, revitalization, and renewal. The approximately $12 million budget includes funds for concentrated blight elimination, the repair of City-owned properties, and vacant lot renewal and beautification.

The HOME GR/OWN initiative complements the Strong Neighborhoods Plan by focusing on vacant lot beautification and reactivation. HOME GR/OWN's mission is to increase access and demand for local, healthy food. With regard to vacant lots, HOME GR/OWN reimagines how they can be transformed from urban liabilities into assets that increase the availability and demand for healthy foods, thereby improving health, supplementing incomes through new job opportunities in the local food supply chain, and creating useful, safe public spaces in disconnected neighborhoods.

The Strong Neighborhoods Plan and HOME GR/OWN work collaboratively to transform foreclosed homes and vacant lots into vital hubs of neighborhood activity by constructing community open spaces, pocket parks, and community gardens and orchards, which enable local residents to grow, harvest, and eat fresh, healthy food.

Stormwater management and rainwater harvesting are central components of creating sustainable gardens and green spaces for both initiatives. HOME GR/OWN's aim is to install one or more green infrastructure BMPs on each lot it converts. Strategies to be employed include bioswales, permeable pavement, stormwater trees, rain gardens, and rainwater catchment (rain barrels and small cisterns), and native landscaping. While the quantities of green infrastructure implemented will vary depending on site location, desired use, and available funding, HOME GR/OWN is committed to maximizing the use of green

infrastructure in every project.

Two HOME GR/OWN lot conversions have been completed for 2014 and incorporate several green infrastructure strategies. Both projects include the installation of 1000-gallon rainwater catchment cisterns to allow reuse of water infiltrated through porous paving for watering the plantings.

- Pocket Park at N. 14th St. – Green infrastructure BMPs include a rain garden, permeable pavers, native plantings, and stormwater trees for a potential capture volume of 9400 gallons during a ½-inch rain event.
- Tree Orchard at N. First St. and Locust St. – total potential capture volume of 5137 gallons during a ½-inch rain event via 45 fruit trees, porous sidewalk, and a bioswale.

Over the course of 2014, HOME GR/OWN is targeting 40 vacant lots for beautification and food-related reactivation, and will seek funding in 2015 to target an equal amount. The Strong Neighborhoods Plan is working to transform 80 lots in 2014, many in collaboration with HOME GR/OWN.

Although the total potential stormwater capture volumes will vary widely and are unable to be quantified until each project is designed and approved, over time both initiatives could make significant contributions to reducing stormwater runoff and harvesting rainfall for reuse. These reductions in flow would ease pressure in vulnerable neighborhoods prone to surface flooding and basement backups resulting from clear water infiltration into sewers.

GREEN INFRASTRUCTURE COSTS

Implementing adequate green infrastructure BMPs to capture the volume of stormwater presented by either *ReFresh Milwaukee* or MMSD would require significant economic investment and depend on meticulous project planning as each methodology has differing potential storage capacities (see Table 4 on page 21). Additionally, economic costs, maintenance, and environmental constraints all impact which strategies would be most practical and efficient for a given project.

Economic consideration of green infrastructure installation is an important factor as initial construction costs can be substantial. Table 8 lists stand-alone costs for different green infrastructure strategies. These prices represent the costs associated with new construction or retrofit projects installing green infrastructure. The figures included here are also compared to the incremental cost, the difference between the cost of conventional construction and that for green infrastructure. For example, if the construction cost of a parking lot is $3 per square foot for conventional pavement but $10 per square foot for porous pavement, the incremental cost is $7 per square foot. Information in this table is adapted from MMSD's *Regional Green Infrastructure Plan*, Table 9, on page 62.

Table 8: COSTS FOR GREEN INFRASTRUCTURE CONSTRUCTION

Green Infrastructure Strategy:	**Cost (per Square Foot)**	**Non-Green Infrastructure Cost (per Square Foot)**	**Incremental Cost (per Square Foot)**	**Sources for Stand-Alone Cost Estimates**
BIORETENTION/BIOSWALE	$24	$7.20	$16.80	Average between PWD[1] and SUSTAIN[2] demonstration project
CISTERN (1000 gallon)	$5000 each unit	$500	$4500	$5/gallon: middle of FCGS[3] range for 1000-gallon cistern
GREEN ROOF	$11.50	$6.55	$4.95	Median PWD cost
NATIVE LANDSCAPING	$0.11	$0.04	$0.07	Middle of FCGS Range rounded up to nearest $1000
POROUS PAVEMENT	$10	$3	$7	$10 per square foot, approximately 90% of median PWD costs.
RAIN BARREL (55 gallon)	$120 each unit	$12	$108	Middle of FCGS range rounded up to nearest $10
RAIN GARDEN	$10	$3	$7	Middle of FCGS range rounded up to $10 per square foot
SOIL AMENDMENTS	$0.11	$0.04	$0.07	Middle of FCGS range rounded up to nearest $1000
STORMWATER TREE	$250 each tree	$125	$125	FCGS cost

[1] PWD is Philadelphia Water Department
[2] SUSTAIN is from *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee* (MMSD, 2011)
[3] FCGS is *Fresh Coast Green Solutions* (MMSD, 2009)

Examination of incremental costs yields important information into the initial costs regarding implementation. These costs may be partially offset through incentive programs (eg, grants, credits), reduced energy usage, decreased stormwater fees, and possibly lowered construction costs as the strategies become more widespread over time. Information and costs pertaining to operation and maintenance of green infrastructure is not included in this discussion, although it can be a significant factor in designing and planning decisions.

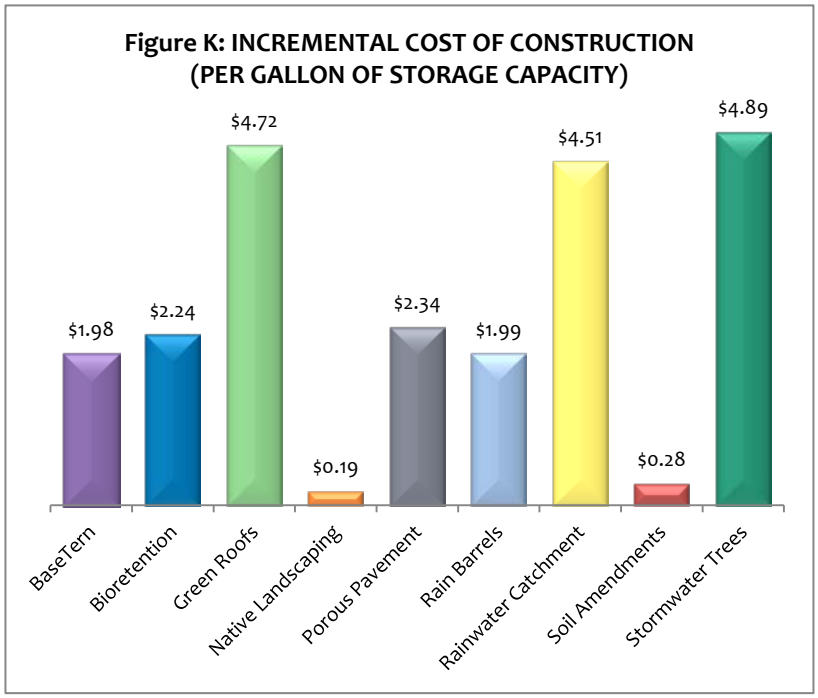
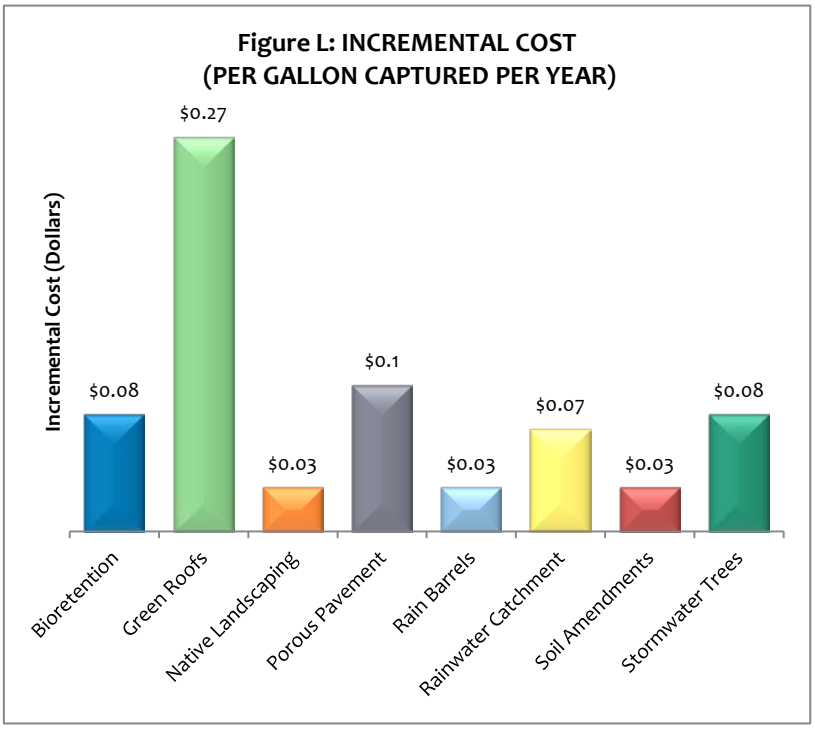


Figure K reflects incremental costs per gallon of storage capacity during construction, and provides a comparison of the relative cost of storage for each type of green infrastructure strategy versus installation of traditional materials and methods. It illustrates the difference in cost versus non-green infrastructure materials (green roof versus tar & gravel roof, for example) for each gallon of stormwater capture desired. This information was adapted from MMSD's *Regional Green Infrastructure Plan*, Figure 23 on page 63.

Figure L represents the incremental cost of each strategy per gallon of water captured over the course of a year. This graphic reflects the efficiency of each strategy to capture stormwater repeatedly throughout the year. As the quantity of rainfall increases over the course of a year, this cost will decrease. In other words, the more water each strategy captures over the course of a year, the more cost efficient it becomes. This information was adapted from MMSD's *Regional Green Infrastructure Plan*, Figure 25 on page 63.



Green Streets implementation also has costs inherent to the plan that have been outlined by the Department of Public Works. Table 9 highlights the costs associated with green infrastructure BMP construction in the Green Streets program, as well as environmental benefits provided by each strategy.

Table 9: GREEN STREETS: PERFORMANCE BY STRATEGY TYPE

Green Infrastructure Strategy Type	Typical Range of Impervious Area Managed per Unit Area	Assumed Impervious Area Managed Per Unit Area	Typical Incremental Cost per SF	TSS Reduction	Total Phosphorus Reduction	Provides Flooding Benefit	Combined Sewer Benefits	Separate Sewer Benefits	Slope Limitations
BIORETENTION	10 to 20	12	$17	80%-100%	40%-80%	Yes	Flood reduction, CSO reduction	Flood reduction & water quality benefit	Must have relatively flat area for bioretention footprint
POROUS PAVEMENT	1 to 8	4	$7	Credit for infiltration; DNR reviewing current standards	Credit for infiltration; DNR reviewing current standards	Yes	Flood reduction, CSO reduction	Flood reduction & water quality benefit	<5% (typical)
TREE TRENCH	10 to 20	12	$7 - $11	Infiltration dependent	Infiltration dependent	Yes	Flood reduction, CSO reduction	Flood reduction & water quality benefit	On steep slopes, trench is somewhat limited and typically becomes a series of individual enhanced tree pits

Based on the stormwater capture goals outlined in both *ReFresh Milwaukee* and MMSD's *2035 Vision* and *Regional Green Infrastructure Plan* for the City of Milwaukee, achievement of the objectives resulting from full implementation of green infrastructure will require significant economic investment. More detailed information regarding green infrastructure capture goals, implementation plans, and costs should be addressed in the City's future Green Infrastructure Plan.

CONCLUSION

The *Green Infrastructure Baseline Inventory* will serve as the main point of reference when the City of Milwaukee develops its Green Infrastructure Plan. As evidenced by the information and data presented herein, policy-makers with the City and in the region will need to make some difficult decisions in a relatively short time frame. That being said, the City of Milwaukee and the Milwaukee Metropolitan Sewerage District are committed to comprehensive and innovative stormwater management and mitigation. In conclusion are the following points for consideration:

- MMSD's *2035 Vision* and *Regional Green Infrastructure Plan* have presented ambitious goals that would have a great impact if adopted by the City of Milwaukee.
- Of the 28 communities in MMSD's service area, the City of Milwaukee contains the largest quantity of impervious surfaces.
- If the City adopts and adapts MMSD's goals, total stormwater capture volume targets could be equal to:
    - 380 million gallons based on the city's impervious surface area, or
    - 173 million gallons based on the city's percentage of MMSD's service area.
- The Water Chapter of *ReFresh Milwaukee* sets a target to increase the volume of stormwater captured by green infrastructure by 10% annually, which would equal 36 million gallons by 2023.
- Current, known green infrastructure capture volume in the City of Milwaukee is approximately 14 million gallons. Additional proposed BMPs could add 19.5 million gallons of capture, for a total of 33.5 million gallons.
- An average year of implementation of MMSD's 2035 goal, if the City aims to capture 173 million gallons, could:
    - Require the construction of new green infrastructure to capture an additional 9.8 million gallons of stormwater.
    - Result in an estimated cost[3] of up to $62 million.
- Implementation of the City's estimated portion of MMSD's green infrastructure capture goals would be extremely expensive and require adding substantial (almost exponential) quantities of BMPs each year.
- Implementation of the City's estimated portion of MMSD's green infrastructure goals would require major political commitment and immediate, comprehensive citywide construction effort.

[3] Based on estimated BMP quantities listed in "Annual Total Needed to Reach Goal" column of Table 6, page 24. Cost estimates adapted from MMSD *Regional Green Infrastructure Plan*, Table 9, page 62.

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liveroof.com/showcase-search

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www.h2ocapture.com/en/GI-Plan

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Reed Street Yards and Global Water Technology Park:
www.watertechnologypark.com/

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www.sewrpc.org/SEWRPC.htm

United States Environmental Protection Agency Green Infrastructure Information (Definitions, Types, About):
water.epa.gov/infrastructure/greeninfrastructure/index.cfm#tabs-2

MAP APPENDIX

MAP A: Milwaukee Watersheds

MAP B: Milwaukee Watersheds - Topography

MAP C: City of Milwaukee Impervious Surfaces – Aerial View

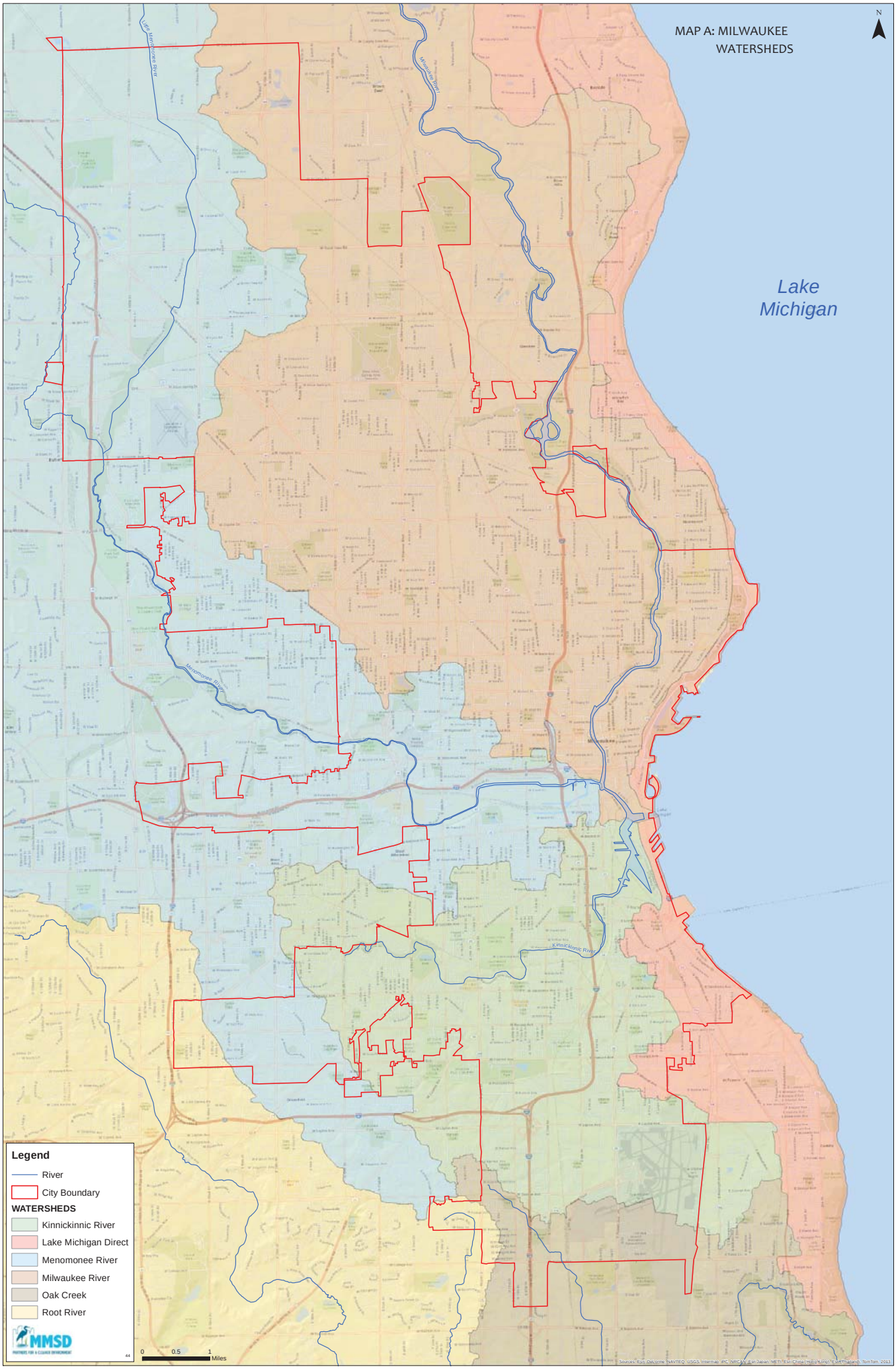
MAP D: Downtown Milwaukee Impervious Surfaces – Aerial View

MAP E: Milwaukee Combined Sewer Area

MAP F: Milwaukee Basement Backups, 2008-2010

MAP G: Milwaukee Basement Backup Concentration Area – Topography

MAP H: Milwaukee Basement Backup Concentration Area


MAP A: MILWAUKEE WATERSHEDS
N
Lake Michigan
Legend
River
City Boundary
WATERSHEDS
Kinnickinnic River
Lake Michigan Direct
Menomonee River
Milwaukee River
Oak Creek
Root River
MMSD
0
0.5
1
Miles

MAP B: WATERSHED TOPOGRAPHY

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin

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Map Milwaukee: Green Infrastructure

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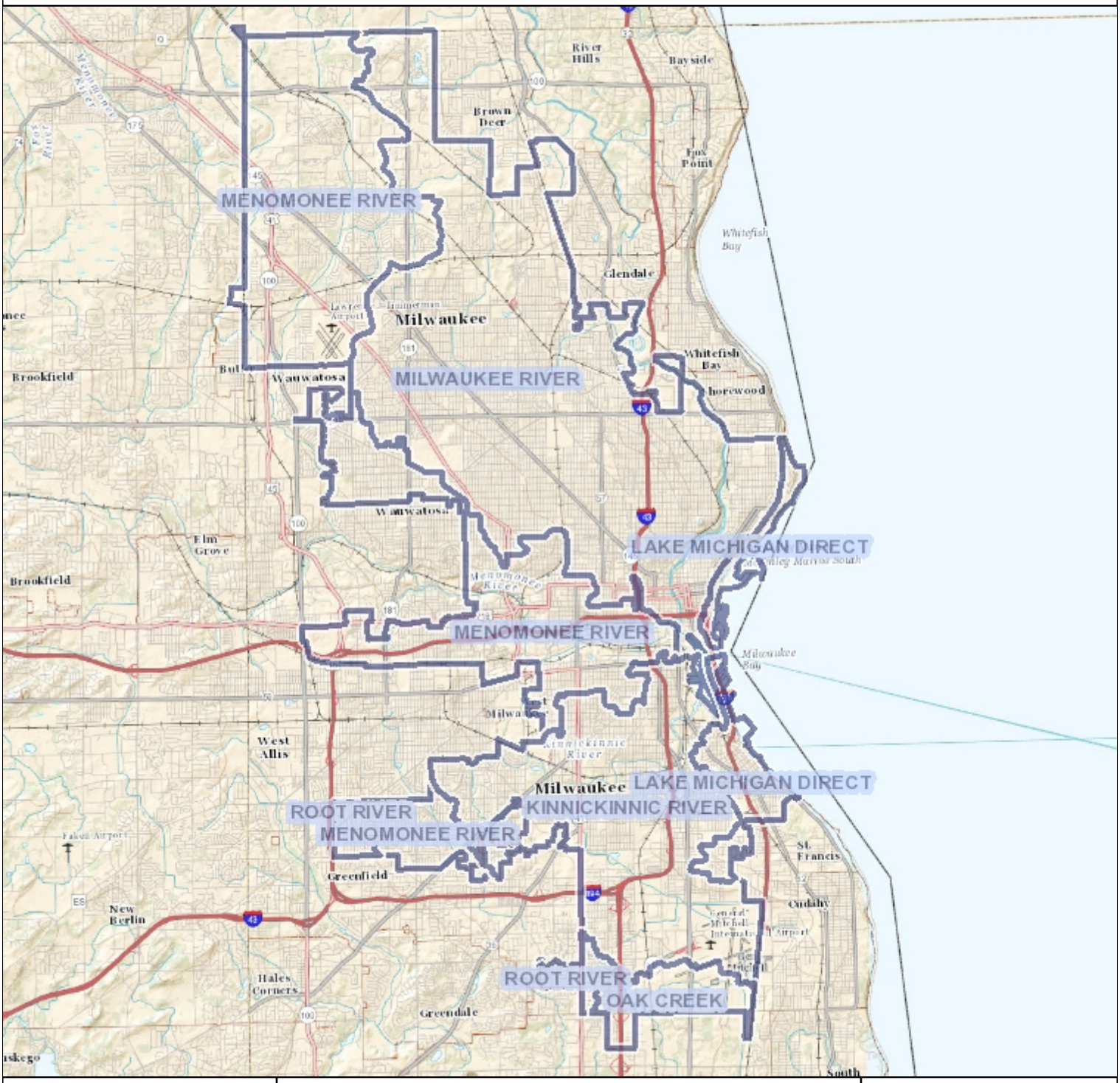
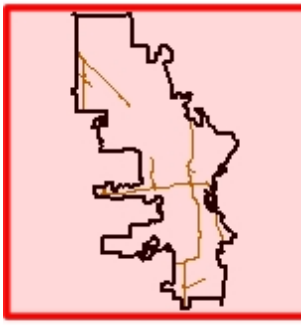
7/1/2014

Map Scale: 1: 164,444

13,703.7 0 6,851.85 13,703.7 Feet





- Legend -

Watersheds

USGS Topo Basemap - 18k and Smaller

- Notes -

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MAP C: IMPERVIOUS SURFACE - AERIAL

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City of Milwaukee, Wisconsin

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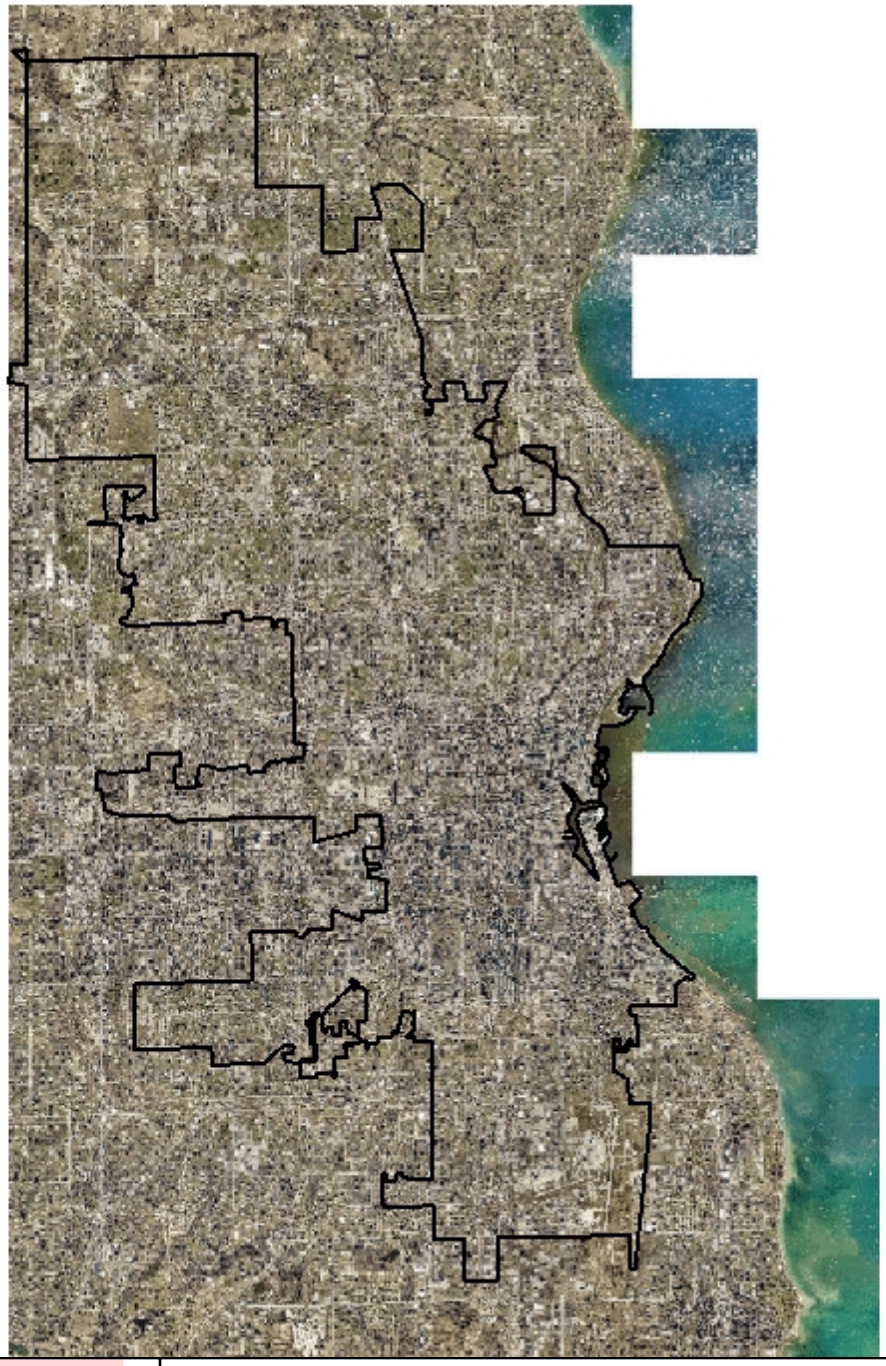
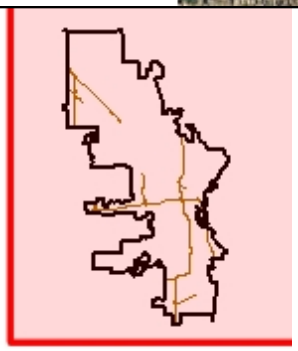
7/25/2014

Map Scale: 1: 185,000

15,416.7 0 7,708.35 15,416.7 Feet





- Legend -

2013 ACUPLUS

Red: Band_1

Green: Band_2

Blue: Band_3

City limits

- Notes -

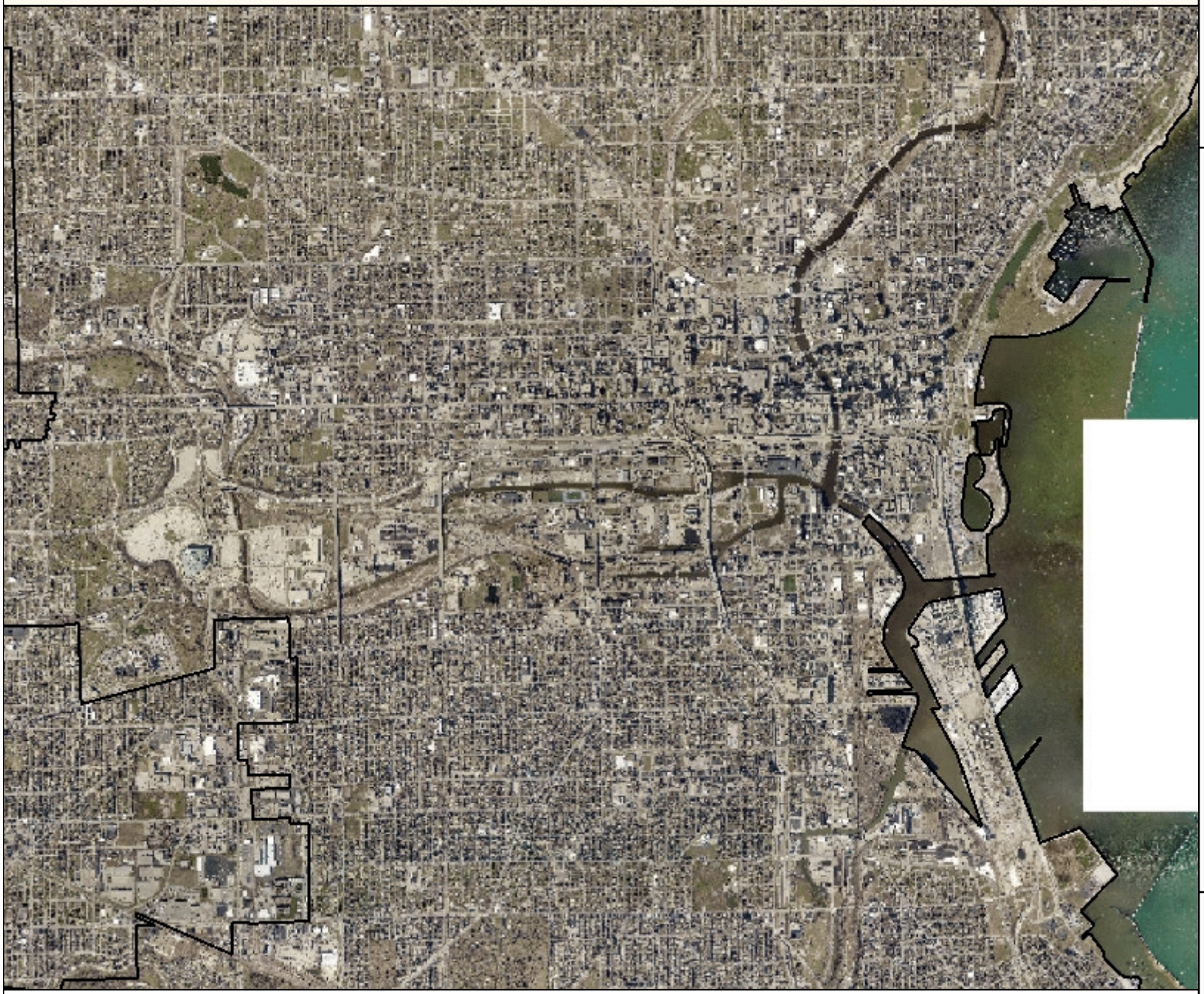
City of Milwaukee

Department of Administration - ITMD

MAP D: DOWNTOWN IMPERVIOUS SURFACES

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin



- Legend -

2013 ACUPLUS

Red: Band_1

Green: Band_2

Blue: Band_3

City limits

- Notes -

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Map Milwaukee: Green Infrastructure

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Map Scale: 1: 43,167

3,597.2 0 1,798.61 3,597.2 Feet

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MAP E: COMBINED SEWER AREA

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin

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Map Milwaukee: Green Infrastructure

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Map Scale: 1: 164,444

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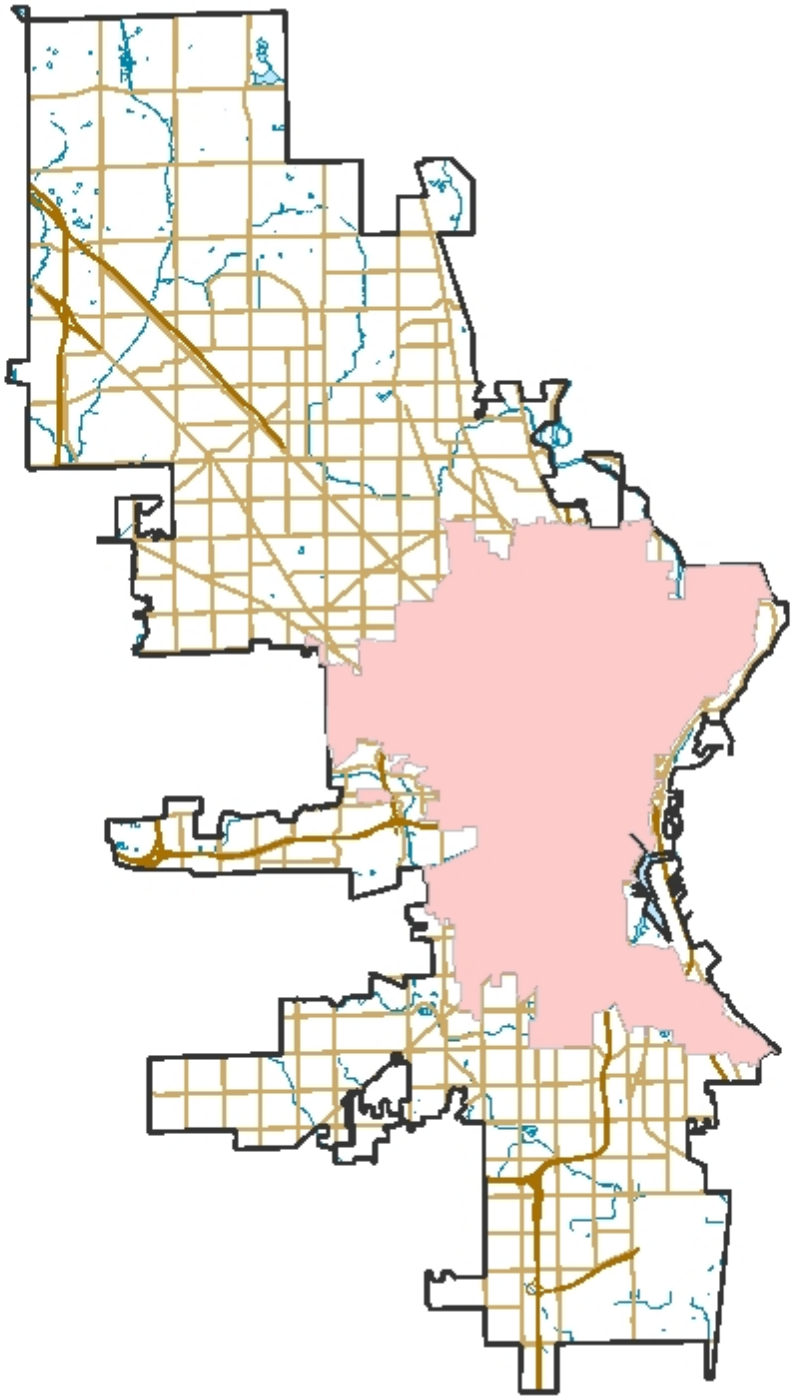

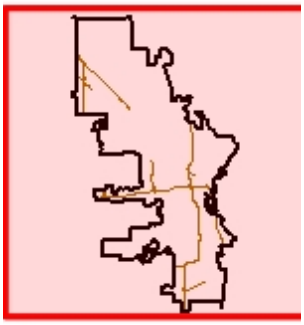

- Legend -

- Combined sewer area
- City limits
- Freeways
  - Freeways
  - Ramps
- Major streets
- Waterways

- Notes -

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MAP F: BASEMENT BACKUPS, 2008-2010

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin

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Map Milwaukee: Green Infrastructure

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Map Scale: 1: 164,444

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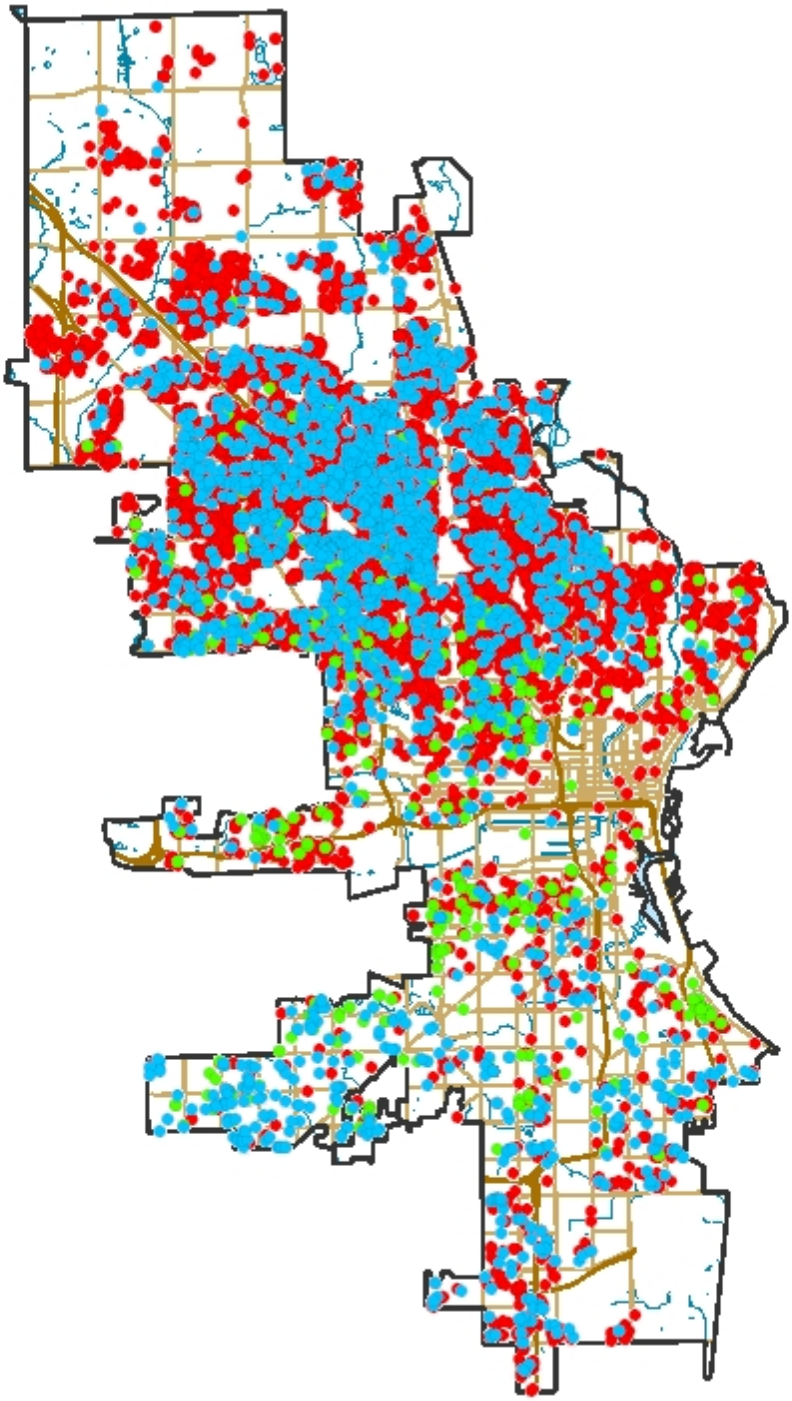

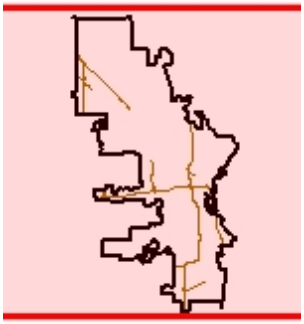

- Legend -

- 2008 basement backup locations (1,785)
- 2009 basement backup locations (658)
- 2010 basement backup locations (11,600)
- City limits
- Freeways
  - Freeways
  - Ramps
- Major streets
- Waterways

- Notes -

City of Milwaukee

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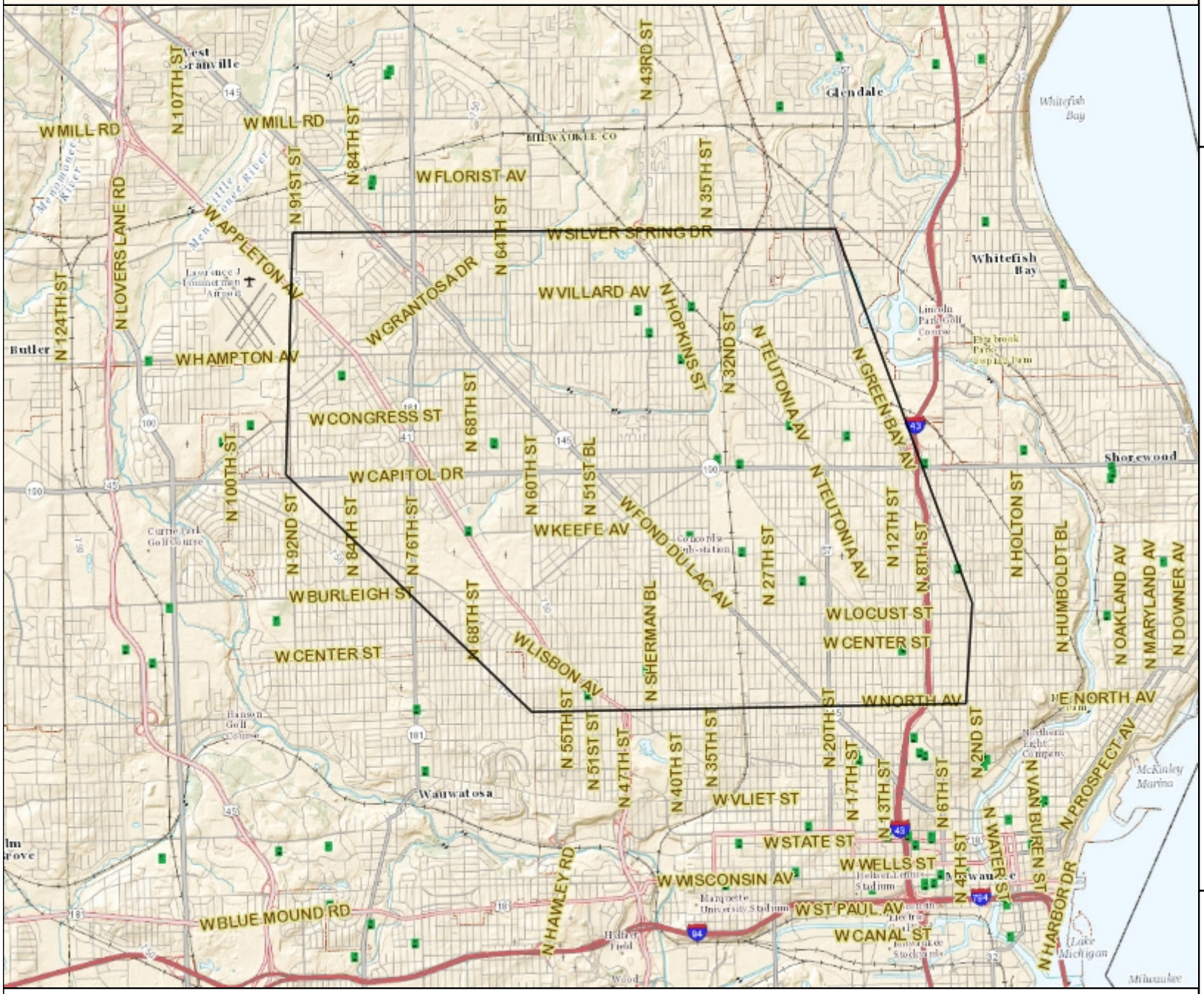
MAP G: TOPOGRAPHY OF BASEMENT BACKUP CONCENTRATION AREA

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin



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USGS Topo Basemap - 18k ar

- Notes -

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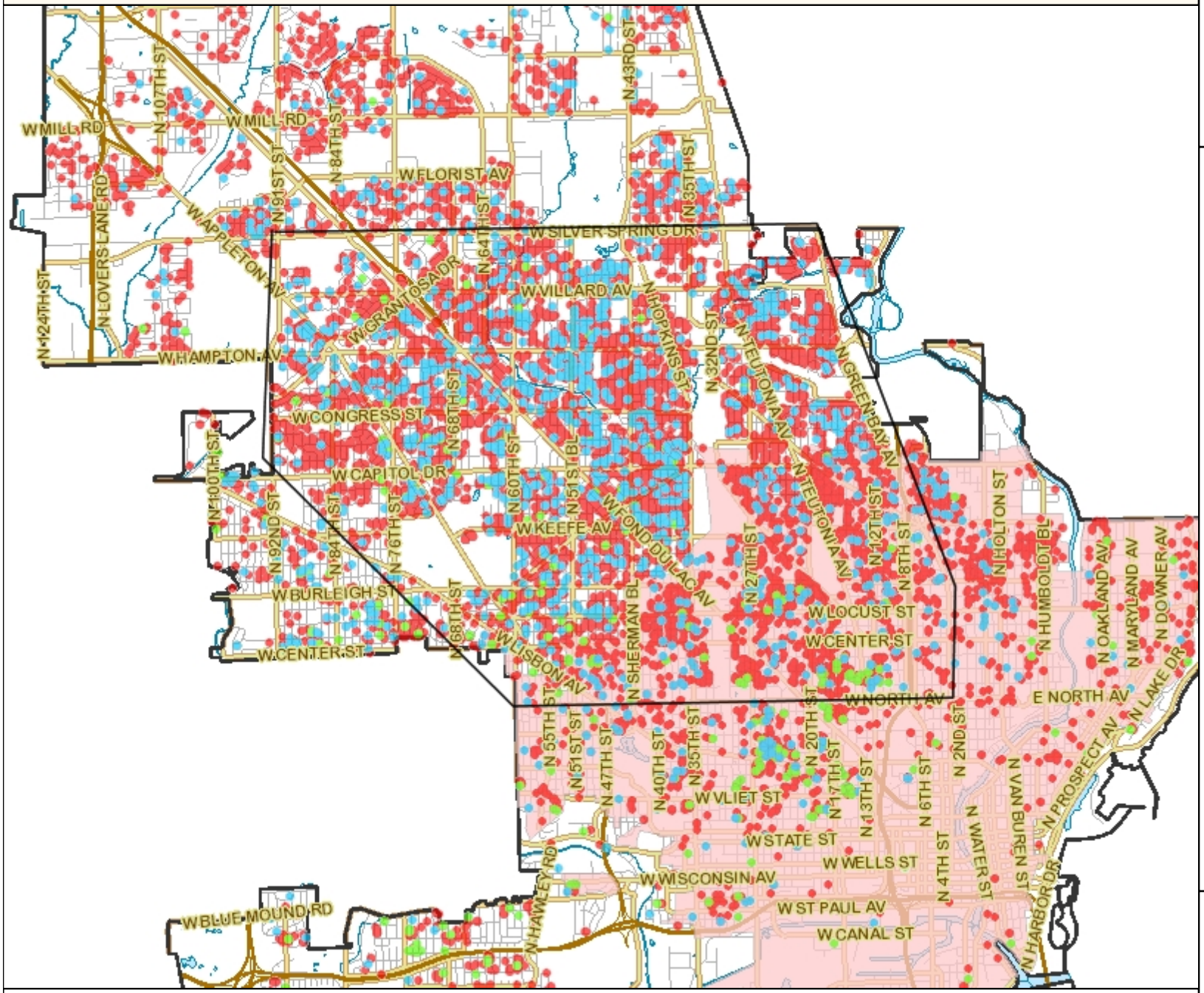
Map Scale: 1: 76,741

6,395.1 0 3,197.53 6,395.1 Feet

MAP H: BASEMENT BACKUP CONCENTRATION AREA

Map Milwaukee: Green Infrastructure

City of Milwaukee, Wisconsin



- Legend -

- 2008 basement backup locatio
- 2009 basement backup locatio
- 2010 basement backup locatio
- Combined sewer area
- City limits
- Freeways
  - Freeways
  - Ramps
- Major streets
- Streets
- Waterways

- Notes -

City of Milwaukee

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Map Scale: 1: 76,741

6,395.1 0 3,197.53 6,395.1 Feet

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